NOTES ON THE GEOLOGY OF SOUTHEASTERN PENNSYLVANIA.

BY THEODORE D. RAND.

The work of the Second Geological Survey of Pennsylvania was very properly directed chiefly toward the economic geology of the State. Had reasonable appropriations been continued, it is probable that a more careful survey would have been made of the area southeast of the Red Sandstone region, and we might also have had what it is a disgrace to the State that we have not: a map of Pennsylvania comparable with that of the New Jersey Survey or to the Philadelphia Sheet of the U. S. Geological Survey. It being the fact, therefore, that this region southeast of the Red Sandstone has been hastily examined by the geologists of the Survey,[1] that their observations, in many particulars, do not agree with those of the First Survey under that most careful observer, Prof. Henry D. Rogers, and also that in this region there is difference of opinion even among those who studied it under the auspices of the Second Survey, it seemed not improper that I should put upon record numerous observations made in the leisure moments of a rather busy life during the past twenty years, in the hope that some little additional light may be shed upon the subject, and as an aid to those who may wish to study the region hereafter.[2]

I have written of some of the rocks discussed in this paper, but to make this one intelligible it will be necessary to repeat briefly some of the facts already published.

The region, covered chiefly with mica schists and gneisses and

[1] "In a single field season of seven months, a geologist who is to report on a county of fifty-six townships has just *three days* (on an average) to *each township;* and in a State with sixty-seven counties, all of equal importance to their inhabitants, and to practical science, it is evident that a State survey can only afford one full season to each county, unless its funds be greatly increased or its duration be indefinitely protracted."—*Second Geol. Survey of Pa.*, chap. 4, p. 20.

[2] Having experienced much difficulty in identifying localities already published owing to the changes of ownership of farms, quarries, mills, etc., I have described outcrops with particularity, perhaps greater than necessary, deeming it safer to err in the direction of clearness.

soil derived from them, is, as is well known, a difficult one for geological study. Exposures are often few and far between; advantage must be taken of every possible opportunity, such as well-digging and boring, and even of the exposures occasionally made by unusually heavy rains, while over large areas it is often impossible to find a single exposure. Besides this, some rocks of definite character are of very limited breadth, while others, well exposed, vary in width so greatly and suddenly that mapping in the usual method of connecting like exposures is very unsafe. Imagine, for instance, the well-exposed limestone and hydromica schist west and northwest of Conshohocken to be represented by scattered outcrops similar to those of the limestones and mica schists of southern Chester county, the intermediate surface being covered with soil as in that region, what geologist could possibly map the rocks as they really exist?

Of the rocks southeast of the Red Sandstone there are three prominent series as to which there is reasonable accord among all geologists:—

I. Rogers' Third Belt—possibly Laurentian, probably a considerable part plutonic. A remarkably straight outcrop of quite uniform, very hard gneissoid rocks, striking about S. 65° W., and extending almost unbroken from near Morrisville, Bucks county, opposite Trenton, N. J., to west of the Brandywine, apparently anticlinal in structure, and the oldest rock of the region. This, called Laurentian by the Second Survey and in my previous papers, I prefer to call by the safer term Ancient Gneiss.

II. Cambrian Sandstone. Rogers' Primal Sandstone, often called Potsdam, No. 1 of the Survey—the oldest fossiliferous rock yet discovered in this area.

III. Limestone, No. 2 of the Survey, Rogers' Auroral Limestone, formerly supposed to be equivalent to the Calciferous, Chazy and Trenton Limestones of the New York Survey,[3] though the recent studies of Prof. Walcott seem to prove that is Cambrian.[4] As to the remainder of the rocks, opinions differ widely. Those covering the largest areas are mica schists and gneisses. Among these gneisses and mica schists are belts of peculiar character traceable

[3] Chap. 4, p. 113, where this opinion is very forcibly asserted.
[4] *A. J. S.*, January, 1894, p. 37, and Vol. XLIV, 1892, p. 469.

for miles, for, as a rule, there are few well-marked sudden variations on the strike line.

These gneisses and schists include Rogers' first and second belts, Mr. Hall's Philadelphia schists and gneisses, and Manayunk schists and Chestnut Hill schists; Prof. Lesley's newer gneiss of the Philadelphia belt. The strike of these accords in the main with that of the ancient gneiss, local deviations being common; the subdivisions vary in width, their borders being usually more or less divergent or convergent. The almost universal dip, northwest of Darby creek, is northwestward, except close to the ancient gneiss, where it is southeastward. It should be said, however, that the apparent dip may not be the true dip, but merely schistosity due to pressure. It is a fact, however, that this schistosity seems to accord closely with changes in the constitution of the rocks.

Southwest of Darby creek a southeast dip prevails. Southwest of the Schuylkill similar schists and gneisses occur northwest of the ancient gneiss.

Minor faults are common, great ones may exist, but this has not been proved. The age of these newer schists and gneisses and their relative superposition is greatly in doubt; indeed, hardly any two geologists have agreed. Fossils not having been found, the arguments are necessarily based upon lithological character and stratigraphical position. It is, I believe, conceded that there is no considerable break of continuity on the line of strike, except that Mr. Hall regards certain hard gneisses in southern Delaware county and some gabbros, as Laurentian, underlying the newer schists and gneisses. The views of geologists may be briefly summed as follows:

Prof. Rogers supposed the structure a simple synclinal, the Chestnut Hill series, his second group, underlaid by the gneiss, which rose to the southeast and to the northwest, his first and third belts.

Above his third belt he recognized the primal (Cambrian) sandstone and a series of rocks which he regarded as of the same age stretching southwestward, and in western Chester county southward nearly or quite to the Maryland line, here overlying the Philadelphia rocks which he saw extending in a series of anticlinals dying out westward under his primal rocks.[5]

[5] *First Geol. Survey of Pa.*, I, p. 228, quoted chap. 4, p. 68: "But to the westward of the Brandywine . . . . the primal series is spread prodig-

Mr. Charles E. Hall, finding in Montgomery county the same succession of rocks southeast of the ancient gneiss as northwest of it, particularly the Cambrian sandstone (then called Potsdam), and the limestone of Huntingdon Valley, supposed to be Silurian, argued that the schists and gneisses of the Philadelphia series succeeding to the southeast must be still more recent,[6] and likewise that the hydromica schists of the South (Chester) Valley hill were Hudson river,[7] and that these last spread through southwest Chester county.[8]

Dr. T. Sterry Hunt[9] made a study of the region, and chiefly on lithological grounds identified the Chestnut Hill series as Huronian, the Philadelphia rocks as Montalban overlying the Chestnut Hill schists.

Prof. James D. Dana referred the mica schists and gneisses of New York island and vicinity, which are certainly identical with those of the vicinity of Philadelphia, to the Lower Silurian.[10]

N. L. Britton wrote of the correspondence between the rocks of southeast New York and northern New Jersey of the gneissic and schistose group and Dr. Hunt's Montalban.[11]

Prof. H. Carvill Lewis[12] identified the newer schists and gneisses as Huronian, and in a later paper[13] contended that many, if not most, of these rocks were "of purely eruptive origin, consisting of syenites, acid gabbros, trap granulites, and other igneous rocks, often highly metamorphosed."

Dr. Frazer referred many of these rocks to the Huronian,[14]

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iously to the southward almost to the southern line of the State." *Geol. of Pa.*, I, p. 154.

A brief but remarkably accurate description of the geology of Chester county was published in a report of the Chester County Medical Society about the year 1857 anonymously. Its delineations of the chief belts of rock crossing the county show the author to have been most familiar with the region.

[6] *Second Geol. Survey of Pa.*, Vol. C[6], x, but for Pottsville, Potsdam is probably intended. *Ibid.*, p. xvii, and pp. 6 and 7.

[7] C[6], p. 12.

[8] C[4], p. 54.

[9] *Second Geol. Survey of Pa.*, Vol. E.

[10] *American Journal of Science*, June, 1881.

[11] *School of Mines Quarterly*, Vol. IX, p. 33.

[12] *Journal Franklin Institute*, third series, Vol. LXXXV, 1883, p. 424.

[13] H. C. Lewis, *Proc. British Association* in *Nature*, October 8, 1885, p. 560.

[14] "Ces mica-schistes, schistes à damourite, gneiss chloritiques et micacés representent la plus méridionale et la plus orientale des trois bandes du Huronien de ce district." *Memoir sur la géologie de la partie sud-est de la Pennsylvanie.* Lille, 1882, p. 37.

though questioning whether the limestone at Brinton's Bridge, north of Chadd's Ford, were Huronian or Laurentian.[15]

Dr. Frazer[16] regarded the South Chester Valley hill rocks as older than the limestones. He also urged[17] that much of the sandy schist area of southwestern Chester county should be regarded as Potsdam.

Prof. C. H. Hitchcock[18] referred the Philadelphia gneisses to the Montalban system of New Hampshire.

Prof. Lesley, in his Final Report, seems to regard the limestones of southwestern Chester county as Laurentian,[19] though this opinion is qualified on p. 128, where it is stated, "If the distinction between the older and the newer gneiss be a valid one, the older gneiss seems to disappear from the surface, going west from the Schuylkill into Chester county, and the newer gneiss seems to occupy the whole field south of the belt of South Valley Hill hydromica slate in Chester."

On p. 120, Vol. I, of the Final Report, Prof. Lesley gives clearly his view of the structure on the Schuylkill section as follows:

"1. The lower, or Philadelphia mica schist and gneiss group;

"2. The middle, or Manayunk mica schist;

"3. The upper, or Chestnut Hill garnetiferous schist group."

". . . . a constant general northwest dip, and these continue for another half-mile to a serpentine outcrop along the south edge of the Bear Ridge[20] older gneiss belt, but with reversed (southeast) dips. Therefore there is here a synclinal basin, and then a great fault, in which must be buried (against the older gneiss mass)

[15] *Memoir sur la géologie de la partie sud-est de la Pennsylvanie.* Lille. 1882, p. 52.

[16] *Second Geol. Survey of Pa.*, Vol. C⁴; *Proc. Am. Phil. Soc.* Dec. 15, 1882, p. 517.

[17] C⁴, pp. 35, 159, 311.

[18] *Trans. Am. Inst. M. E.*, 1883, 1884, Vol. XII, p. 68.

[19] "In Pennsylvania the highland gneiss areas do not show their marble beds enough to be well studied, ... but where they are thus exposed . . . . in southern Chester county . . . . they reveal the same facts as in the New Jersey Highlands" (Final Report, p. 110).

"There seems to be no probable objection to be urged against recognizing in the rocks of the Highlands of New York, New Jersey and Pennsylvania the rocks of the Adirondack region and of the Laurentian mountains of Canada; therefore the term *Laurentian gneiss* has been freely used in the reports of progress of the Survey to signify the rocks of the Pennsylvania Highlands" (*Idem*, p. 62).

[20] Probably a misprint for Buck Ridge.

the Manayunk and Philadelphia subdivisions; at least, this is the best explanation of the structure which has been obtained."[21]

From this brief summary it will be seen how very diverse are the views of the eminent geologists quoted, and why a more minute study was needed, for it seems incredible that upon the same facts, clearly and correctly stated, conclusions so varied could be reached by men so well qualified, some of whom, however, made no personal study of the outcrops.

The region is a portion of the great Piedmont plateau, but in its northern part nearly covered by the Red Rocks. The Philadelphia rocks (in part) extend southwestwardly through Maryland, where they have been studied by the late Dr. Williams, whose papers on the subject are very clear and throw much light on the questions which arise further north.[22]

Dr. Williams divides the rocks of the Piedmont belt in Maryland into two distinct classes. "One completely crystalline, and whatever their origin retaining no certain evidence of clastic structure, and confined to the eastern portion of the plateau. The second class are semi-crystalline, and while they have been subjected to a certain amount of metamorphism and alteration, they still plainly show that they were once sediments of ordinary type, not more altered than formations which in other locations have yielded fossils, so that there is no reason to suppose that their age will not be determined on palæontological evidence."[23]

That this conclusion is not unwarranted may be inferred from his remarks on the "quartz schist" under which he describes most clearly and unmistakably the Cambrian sandstone of Pennsylvania, which contains *Scolithus* in Chester county and abundant fossils further west. He says "whatever the origin of the quartz schist may have been, it is closely allied to the gneiss into which it grades by imperceptible transitions."[24]

It will be noticed that in Maryland the highly crystalline rocks

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[21] *Trans. Am. Inst. M. E.*, 1883, 1884, Vol. XII, p. 123.

[22] Extract from the *Guide Book of Baltimore*, prepared for the American Institute of Mining Engineers, February, 1892; *U. S. Geological Survey Bulletin*, No. 28, 1886; *Bulletin Geol. Soc. Am.*, Vol. II, p. 301.

[23] *Guide Book*, pp. 79, 80.

[24] "The cleavage planes of the quartz schist are due to their layers of muscovite. . . . . Its most characteristic feature . . . . long crystals of black tourmaline . . . . invariably broken and their fragments stretched along one line." (Williams' *Guide Book*, p. 103).

are to the *east* of the schistose belt. This belt, according to my observations, extends but a short distance into Pennsylvania, near the Delaware line, and is too poorly exposed to much more than indicate its existence, but there is evidence that it is largely intrusive. The map of Dr. Williams shows the rocks occupying very irregular areas in Maryland. In Pennsylvania, however, the margins of the areas are nearly straight, or at most gently curving lines, with remarkable uniformity of dip (cleavage?) over large territory.

The work of Dr. Williams was well supplemented by that of Prof. Frederick D. Chester on the gabbros of Delaware,[25] confirming Dr. Williams' results, but seemingly proving the passage of the massive gabbro into gneisses such as are common in the Philadelphia schists and gneisses.

If, starting at the northeast, we take a bird's-eye view of the region, we shall find it a triangle with the apex near Trenton, N. J., measuring about seventy miles southwestward with a base of about eighteen miles at the Octorara creek, the dividing line between Lancaster and Chester counties.[26]

At this apex we find the ancient gneiss flanked on the northwest by the Red Rocks, and on the southeast by the Cambrian sandstone, closely southeast of which are rocks typical of Mr. Hall's Manayunk series.

Southwestwardly we see the ancient gneiss widening and becoming a prominent ridge, known as Buck Ridge. The Cambrian sandstone continues on its southeasterly flank for a distance of nearly twenty miles, in its turn flanked on the southeast by limestone for a short distance, the schists and gneisses following.

Returning now to the ancient gneiss, we see it fork near Willow Grove, about eighteen miles from our starting point being divided and its central part overlaid by the Cambrian sandstone. The two branches of the gneiss continue southwestwardly, the northerly soon covered by the Red Rocks, but reappearing and covering a large extent of territory in northern Chester county, the southerly extending southwestward, narrowing, and at the Wissahickon becoming obscure or covered, then reappearing and widening

[25] *U. S. Geol. Survey Bul.*, No. 59.

[26] Except in the Chester valley, and to a very limited extent south of it, my researches have not extended west of the Octorara.

rapidly, crossing the Schuylkill with a width of a mile; Darby creek, seven miles from the Schuylkill, with a width of four miles; Crum creek, three miles beyond, with a width of five miles. Here it again forks, the southerly fork, only about a mile wide and extending not over five miles in length, narrows and ends southwest of and near Westtown School; the northerly, with a width of four miles, continues to the north of Westtown School, underlies West Chester, then narrows to a little over a mile, crosses the Brandywine just above the forks, and ends at Northbrook, about two miles beyond.

In nearly all this course we find the adjacent rocks to be schists and schistose gneisses, in which are outcrops of the sandstone.

Returning now to the vicinity of Willow Grove, we find, going southwestward, the sandstone divided by a limestone area. The northerly and much larger branch of the sandstone continues, with interruptions, to Valley Forge, whence it continues southwestwardly as the very prominent North Chester Valley Hill to Quarryville, in Lancaster county.

The southerly area of the Cambrian ranges through Edge Hill, here approaching very closely that mentioned as being on the southeasterly flank of the ancient gneiss, thence, through Barren Hill, to Spring Mill on the Schuylkill. Here it becomes obscure, but it may be traced westward as far as Wayne, Delaware county, while the sandy micaceous rocks, which seem to replace in part the typical sandstone, continue uninterruptedly. In middle and western Chester county the typical rock again appears among the micaceous rocks.

The limestone which first appears a short distance southeast of Willow Grove rapidly widens and forms the Montgomery or Plymouth Valley and westward the Chester Valley.

A little east of the Schuylkill this great area of limestone is in its turn divided by a hill of hydromica schist, with no sandstone visible between it and the limestone. West of the Schuylkill, the southerly areas of limestone and sandstone become insignificant, while the hydromica schist, not over a quarter of a mile wide at the river, broadens (chiefly by two remarkable promontories) until one and a half miles west of the river its breadth exceeds two miles, while the northerly area of the limestone forming the floor of the valley two and a half miles wide at the Schuylkill narrows

to less than a mile. From the Schuylkill westward it is known as the Chester Valley.

Close to the southerly arm of the limestone occur mica schists, not unlike those on the southerly side of the southerly ancient gneiss. These schists, very narrow at the Schuylkill, widen rapidly westward, while the hydromica schists narrow. Near Northbrook Station, on the West Branch of the Brandywine, these mica schists appear to unite with those on the southeast of the ancient gneiss, while the gneiss itself disappears from view.

This disappearance is accompanied by a large outcrop of serpentine, a rock which northeastward seems to flank the ancient gneiss on both sides in scattered outcrops. Here the northerly mica schists become more quartzose and gneisses abound, much less massive, however, than the ancient gneiss, and form steep and high hills.

Included in the area of Prof. Rogers' first belt is the porphyritic gneiss, occupying a narrow outcrop at the Schuylkill but widening westward. It is remarkably uniform in its composition and from its hardness makes a prominent hill through most of its course.

In the same area are the Fairmount and Frankford gneisses, the former apparently anticlinal at the Schuylkill, the latter with the abnormal strike of nearly east and west. Both are noted for the rare minerals which they contain.

Resting on the higher summits of the newer gneisses and schists, southeast of the ancient gneiss, are patches of the Bryn Mawr gravel, described by Prof. Lewis. At a much lower level, overlying similar schists and gneisses, occur the Delaware river gravels and clays.

It would be most systematic to study the region, beginning with the most recent rocks. So far as the gravels and clays are concerned this could readily be done, but they are so much better exposed in New Jersey and Maryland and have been so well studied by the geologists of those States and by Mr. Woolman that nothing I could add would be of value.

Below these, however, it is the probably newer rocks about which there is the greatest difference of opinion, while as to the older there appears to be less question. For this reason, and also because the ancient gneiss forms a nearly straight almost unbroken ridge through about fifty miles of the region, I have deemed it

best to begin with it, and to consider next the sandstone and limestone, and afterwards the more doubtful rocks.

In endeavoring to describe the rocks clearly and at the same time to avoid as far as possible the description of areas simply of geographical or political division, I have found some repetition unavoidable, which I trust will be pardoned.

The following is the classification of the rocks of the region, except the gravels and clay, by Prof. Rogers, Mr. Hall and myself, the latter showing my view of the Schuylkill section, except that the northwesterly ancient gneiss is not visible at the Schuylkill, though to be seen not very far off, both to the northeast and southwest, and that the northwesterly Cambrian sandstone and Cambrian schists are concealed at the Schuylkill. The Frankford gneiss does not reach the Schuylkill.

Prof. Rogers.	*Mr. Chas. E. Hall.*	*Theo. D. Rand.*
S. E.	Philadelphia mica schists and gneiss group.	Frankford gneiss.
		Fairmount gneiss.
First Belt.		Manayunk schists and gneisses.
		Porphyritic gneiss.
	Manayunk schists.	Manayunk schists and gneiss.
Second Belt.	Chestnut Hill schists, including steatite and serpentine belts.	Chestnut Hill schists, including steatite belt.
		Cambrian sandstone.
		Spangled schists.
		Lafayette serpentine.
		Rogers' altered primal.
Third Belt.	Laurentian.	Ancient gneiss.
		Rogers' altered primal.
Altered Primal.		Schists, spangled and garnetiferous.
		Cambrian sandstone.
Auroral.		Cambrian limestone.
Primal.	Hudson river slate.	Hydromica schists.
Auroral.	No. 2 limestone.	Cambrian limestone.
Upper Primal.		Upper Cambrian schists.
Primal Sandstone.		Cambrian sandstone.

Prof. Rogers.	*Mr. Chas. E. Hall.*	*Theo. D. Rand.*
Lower Primal.		Lower Cambrian schists and gneisses (Chester county gneiss).
		Lower Cambrian conglomerate.
		Ancient gneiss.
		Red sandstone.

It is well recognized that no thorough study of the crystalline rocks can be made without a study of sections under the microscope. I do not feel myself competent to undertake this, but hope it may be done by more able hands, when undoubtedly much light will be thrown on many points now obscure. To this end it is my intention to present to the Academy, as soon as I can properly label it, my collection of the rocks of the region, which I believe to be nearly complete.[27]

In preparing these notes I have been most generously aided by many persons—by information, by taking me to points of interest and by hospitality. Indeed, I may say that I have never asked assistance but it was most freely tendered by owners of farms, of quarries and others, and I regret that I cannot name all to whom I am thus under obligation, but among them I feel that especial thanks are due to Mr. Alfred Sharpless, of West Chester; to Mr. William W. Jefferis, to Dr. Charles Schäffer, to Mr. John L. Balderston and Mr. Eli Thompson, of Kennett Square; to Messrs. David and Harry Wilson, of Gum Tree; to Mr. William B. Harvey, of West Grove; to Mr. Thomas H. Windle, of Coatesville, and to Mr. Walter J. Baldwin, of Romansville; and for photographs to Dr. and Mrs. Charles Schäffer, Mr. William C. Stevenson, Jr., Mr. John C. Browne and Mr. George Vaux, Jr.

The Geological Map.

With this paper I have deposited with the Academy a map, on which I have represented the rocks as I have found them, except minor details impossible to be shown on a map of this scale.

[27] Since this was written the Pennsylvania Legislature has made an appropriation and the United States Geological Survey has undertaken the further study of the geology of the State, Dr. Florence Bascom, Professor of Geology in Bryn Mawr College having been placed in charge of the southeasterly part so that my hope will in all probability be realized within a few years.

This map is not intended for publication at present, because I have been unable to procure a trustworthy topographical base. If, as now seems certain, the excellent work of the U. S. Geological Survey, as shown in the map of Philadelphia and vicinity, shall be extended westward, it will give me pleasure to revise this work.

I do not wish to be understood as believing that the whole area upon which is represented the newer schists and gneisses is covered by rocks of one age. Future and more careful study will doubtless divide this area, and I believe it will be made to appear that paleozoic clastic rocks have been penetrated by igneous rocks both basic and acidic, and that the resulting complex has been very greatly metamorphosed and folded by dynamic action.

The topographical base of the map presented, but not published, was prepared from other maps, for the use of the Convocation of Chester, by Mr. Charles G. Darragh, to whom I am indebted for copies. From personal observation I can say that there seem to be errors in all the maps. That which I have used for fieldwork in Chester county, and probably one of the best, is Breou's atlas. The maps are of varied large scale, but when reduced to one scale will often not even approximately register, while the orientation is often in error. The boundaries shown are approximate only. Exposures are rarely sufficient to make them accurate.

The Ancient Gneiss.

The rocks forming the long, nearly straight, Buck Ridge, and extending from near the Delaware at Trenton southwestward for some fifty miles, are, I believe, universally admitted to be the most ancient rocks of the region, and to be, probably, the equivalent of the Highland gneiss of New Jersey and New York. They appear to be to a considerable extent of plutonic origin.

There has been no controversy in regard to them in their range through Bucks, Montgomery and part of Delaware counties. Exactly similar rocks continue in the same strike line to range through northwesterly Delaware county and Chester county, but in regard to this portion geologists do not agree. My observations lead me to distinguish these from what I regard as the more recent series by the following characteristics:

Ancient Gneiss.	*Philadelphia Newer Gneisses.*
Very compact and very hard, never schistose unless decomposed.	Sometimes very compact and hard, but always more or less schistose; usually very schistose, often soft.
Stratification, or foliation, generally obscure, never minutely plicated.	Stratification, or foliation, rarely obscure; often much plicated, both minutely and on a large scale.
Weather into (1) schist-like masses, which, however, will not readily cleave. (2) Frequently into very hard nuclei surrounded by concentric coats of decomposed and decomposing rock (vulg. "niggerheads"). (3) Frequently into loam containing angular fragments of blue quartz, but almost always intermixed with 1 or 2, and very rarely showing mica in the soil.	Weather into irregular masses, but more frequently into loam, often showing mica abundantly in the soil. The porphyritic gneiss only shows the concentric (boulder) decomposition.
Blue quartz very frequently present; particularly shown in the soil derived from the rock.	Blue quartz absent or very rare.
Rocks often uniform over large areas.	Rocks usually vary greatly within short distances on the dip line.
Margins usually marked by steep slopes, making a well-defined hill or table-land on the strike line.	Marginal slopes gentle, no extensive well-defined hills on the strike line, except the porphyritic gneiss and except west of the Brandywine.
Feldspars disseminated granular, rarely in crystals of any size, and when so porphyritic. Usually triclinic.	Feldspars often segregated, or in veins, beds or dykes, often large crystalline masses (pegmatite), usually orthoclase or microcline.
Micas, chiefly biotite in very small quantity and disseminated; muscovite non-existent, or very rare.	Micas, chiefly muscovite, generally abundant, often forming a large part of the rock, also in crystals and cleavage masses. Biotite, however, not rare.

Ancient Gneiss.	*Philadelphia Newer Gneisses.*
Basic trap dykes common, usually small.	Basic trap dykes unknown to the northeast (except some of the hornblende rocks, which are probably altered diorites). They occur southwest, but are not common. Granite or pegmatite common.

As has been stated, the ancient gneiss forms a hill, usually prominent, from near Morrisville, on the Delaware,[28] opposite Trenton, N. J., to Northbrook, on the West Branch of the Brandywine, a distance of about fifty miles.

In this distance it is unbroken, save by narrow gaps, most of them with high precipitous sides. In the northeast it is bounded on the northwest by the Red Rocks, and on the southeast by the Cambrian, with iron-bearing clays. As stated, the hill which it forms is known as Buck Ridge.[29] Its structure is apparently anticlinal, but it seems probable that this is due to foliation from dynamic action. The dips vary so widely in short distances, and are usually so steep, that almost any structure may be built upon them.

As has been stated, Buck Ridge forks a little west of the Pennypack, receiving a basin of Cambrian sandstone, which divides it into two areas, the northwesterly, soon concealed beneath the Red Rocks but rising beyond the Schuylkill, to form part of the azoic region of northern Chester county, north of the Cambrian of the North (Chester) Valley Hill, and extending beyond Honeybrook in the northwestern part of Chester county.

Near Feasterville is the only limestone outcrop occurring in this gneiss (Van Artsdalen's quarry). Accompanying the limestone

[28] In the final report, *Second Geol. Survey of Pa.*, Vol. I, p. 125, it is stated that the *Philadelphia group* narrows more and more, but reaches the Delaware at Easton; but on p. 79 it is stated that the *old azoic gneiss* is seen rising from beneath the mesozoic brown sandstone at the Delaware opposite Trenton. According to my observations the gneiss hill is northwest of the Cambrian sandstone ridge which reaches the Delaware just above the Hancock street bridge, Trenton, N. J. The ancient gneiss I have not seen northeast of the cut of the Trenton Cut-off Railroad, near Woodbourne, six miles south 70° west of Trenton. The rocks exposed in the river below the Hancock street bridge and thence southeast to the Pennsylvania Railroad bridge are typical Manayunk gneisses.

[29] Bear Ridge, *Final Report*, I, p. 175, is probably a misprint. Cf. *idem*, p. 79.

were many minerals, among them graphite, or plumbago, of which a mine was opened southeast of Feasterville, and not far from Van Artsdalen's.

This is probably the mine referred to in the Final Report, p. 478, where it is stated that a mine of very pure plumbago was worked a century ago near Bustleton, Bucks county. Bustleton, however, is some eight miles to the southeast, and is in Philadelphia county.

The southeasterly arm continues as a high hill through Abington, but near Waverly Heights sinks and is shown only by loose masses, and in one quarry. This quarry is of special interest, because here we have the gneiss dividing two closely adjacent areas of Cambrian sandstone, precisely similar in character and little more than half a mile apart on a geographical line, which would be a little longer than the line of dip. The gneiss in this quarry (west of the Limekiln pike, a quarter of a mile south of Edge Hill village) dips N. 60° W. 55°, the southwesterly Cambrian S. 10° E. 70°, S. 20° E. 70°, the northwesterly strikes about S. 60° W. vertical.

A marked change in the topography is here noticeable. The long straight Huntingdon Valley (limestone) has ended, the gneiss ridge has disappeared, while the northwesterly Cambrian sandstone ridge rises to a considerable elevation, forming the southeast bounding hill of that part of the great Montgomery-Chester limestone valley known as the Plymouth Valley. This hill, however, trends more southward than the rocks, so that the ancient gneiss, the southeasterly Cambrian, and the schists which lie to the southeast of the latter strike into it. The northwesterly slope of the hill is much more steep than the southeasterly. Westward, toward the Wissahickon, the former increases, the latter decreases, until at Chestnut Hill the southeasterly slope has disappeared, while the northwesterly is quite steep and probably over 300 feet in vertical height.

Where the North Pennsylvania Railroad crosses this hill at Edge Hill village, south of Edge Hill Station, the hill is wholly of sandstone. Following the crest of the hill southwestward, we find no exposures, but soon the rock fragments in the soil are wholly of the ancient gneiss, while the northwesterly Cambrian sandstone forms a subordinate hill to the northwestward, (this last becomes

more and more prominent westwardly, forming Barren Hill). The gneiss fragments are soon succeeded by schists and these soon form the entire hill from a point north of Chestnut Hill to southwest of the Wissahickon. On the north flank of this hill is apparently a nonconformable contact between the schists, the sandstone and the ancient gneiss.[30]

On the Wissahickon, I have failed to find the ancient gneiss, the schist occurring within a thousand feet of the Barren Hill Cambrian sandstone, with low ground intervening, but on Northwestern avenue, the northwest boundary of Philadelphia, it appears within two thousand feet of the Wissahickon, soon attains an elevation of some three hundred feet, and widens rapidly toward the Schuylkill. It is this rock that terminates westward toward Barren Hill, the ridge to which the Ridge Road owes its name, a narrow hill of schists and gneisses cut off from the adjacent table-lands of Germantown and Chestnut Hill on the north, Ardmore and Bryn Mawr on the south, by the valleys of the Wissahickon and the Schuylkill, which here both run in a general course nearly that of the dip of the rocks, 1.25 to 3 miles apart. The summit of the ridge is nearly level, while the flanks are much serrated by the valleys of small streams flowing eastward into the Wissahickon, and westward into the Schuylkill.

The Wissahickon and Schuylkill sections, though so short a distance apart, show clearly the great changes in the rocks of this region within short distances. On the Wissahickon, as has been stated, the schists are within a thousand feet of the sandstone. On the Schuylkill they are over a mile apart. The dips are almost all steep.

At the Schuylkill the ancient gneiss hill is most prominent. Nearly a mile in width with very steep slopes it rises to an elevation of four hundred feet. The Schuylkill gap shows almost precipitous escarpments toward the river. Westward, the same steep slopes on the sides prevail for about three miles, the belt widening westwardly. The summit is comparatively level, and is traversed for many miles by the Spring Mill road.

Near the line of the Pennsylvania Railroad and the Lancaster turnpike the floors of the adjacent valleys have risen so that the

[30] *Proc. Acad. Nat. Sci. Phila.*, 1890, p. 90.

hill, while reaching 450 feet to 500 feet in its highest ground, is no longer very prominent. The Pennsylvania Railroad summit west of Villa Nova, in a cut about twenty-five feet deep, is 430 feet above ocean level. The gneiss is here two and a quarter miles wide. Further southwestward it still widens, extending on Darby Creek from the Roberts road and the Coopertown and Newtown road to Devon Inn, a distance of three and a half miles. Although no longer so bold a hill, its characteristics may be seen on the old Roberts road, laid out near its eastern base and so hilly that a new road, Bryn Mawr avenue, was laid out a short distance east of it, and in the schists, to avoid the hills. West of Darby Creek it still widens, and east of Crum Creek attains its greatest width, about five miles; between Crum and Ridley creeks it is divided by a valley of schists, the northerly and main arm continuing, the southern arm ending before it reaches Chester creek.

The northerly arm is about three miles wide at West Chester, thence it narrows, crossing the Brandywine above the forks and ending near Northbrook.

There being difference of opinion about the areas occupied by this gneiss in Delaware and Chester counties, they will be given somewhat in detail, premising that I include in it only the hard non-schistose rock shown in the Schuylkill section, and along the Pennsylvania Railroad between Rosemont and St. David's Stations, where it is sharply differentiated from the schists which adjoin it on both sides.

Mr. Hall found difficulty in distinguishing the schistose gneiss from the decomposing ancient gneiss,[31] but my experience has been that they weather so differently that few mistakes would be made if nothing but the soil were carefully examined. Added to this, however, it is hard to find, except in the small tract southeast of West Chester, an area of the ancient gneiss of more than a few acres without unmistakable evidences of its presence; especially is this true of the margins where erosion has been most active. Among others, the area colored correctly Laurentian in C^6, northwest of Bryn Mawr, is changed on that in C^5, to schists, Mr. Hall

[31] "Many of the syenitic rocks of the Laurentian are weathered to such an extent that it is, in many cases, impossible to distinguish them from the adjacent and overlying feldspathic schistose gneisses, and it is therefore impossible to draw a definite dividing line between them" (C^5, p. 92).

saying (p. 22), "I have since been able to trace the schistose rocks all the way from Bryn Mawr to the serpentine localities in the vicinity of Wayne in Radnor township, thus connecting the two areas and proving the schistose rocks to extend across the Laurentian belt. . . . ."

I have already published[32] a number of localities within this area where the undecomposed hard ancient gneiss of most typical character may be observed. Since that time it has been exposed in many other places within the region thus changed, notably in quarries on the Wayne estate, east of the northwest branch of Ithan creek north of the road from Radnor Station to St. David's Church; in a well 70 feet deep on Mr. Robert Stewart's property, near St. David's Station; in a large well 50 feet deep on Pennsylvania Railroad property, close to Radnor Station, dug in 1892–1893, as well as at many localities on both sides of Darby creek.

The northwest border line being the most regular and best defined, it will be traced first. With the map in C^6 my observations agree, but the later map in C^5 is certainly in error as to the northwest boundary as well as the southeast. The schists do occur north and northwest of Radnor Station, in Cream Valley, but not at all east or south of that valley. Within a short distance are at least a dozen conspicuous outcrops of unmistakable ancient gneiss. The line is nearly straight S. 63° W. from the Schuylkill through Lower Merion and Radnor, as far as St. David's Station, where the railroad emerges from it through a cut in which the rock was well exposed; thence to Devon the border line is about S. 80° W., and thence to West Chester S. 60° W. Northwest of West Chester it bends rapidly southward, crossing the East Branch of the Brandywine south of Copesville, and then still curving southward crosses the West Branch of the Brandywine east of Northbrook. The S. 60° W. line is not strictly so, but curved, with that as the general direction.

The southeasterly boundary from the Schuylkill to Rosemont is so well defined by the ridge itself as to be unquestionable.

At Rosemont (in Lower Merion, Montgomery county, but very close to the Delaware county line) in excavations about the station the spangled schists were exposed, particularly in wells and in the

[32] *Second Geol. Survey of Pa.*, An. Rep., 1888, part iv, p. 1573 *et seq.*

trenches dug for the abutments of the railroad bridge at Rosemont Station, dipping S. 45° E. 50°. About 500 feet northwest was an old quarry showing the ancient gneiss with abundance of large masses on the surface. It is exposed also in the bed of the Delaware-Montgomery county line road, about a quarter of a mile northwest of Rosemont Station. About a quarter of a mile southwest of Rosemont Station the old Lancaster road, or Conestoga road, crosses a small stream, a branch of Meadow-brook, and then going westwardly climbs the gneiss hill. About 800 feet east of this stream the schists are exposed in the road; about 600 feet west of it the gneiss is well exposed in a quarry on the north side of the road, the rock dipping southeast 65°.

On Ithan creek the schists may be seen close to Bryn Mawr avenue, thence northward the banks are of the gneiss to its source, there being many exposures.

On the Radnor and Chester road, occupying from Ithan P. O. to the mouth of Meadow-brook the watershed between Ithan and Darby creeks, the schists are exposed near the Roberts road and Darby creek; thence northwestward for miles the gneiss is exposed at frequent intervals.

On the right bank of Darby creek, the Coopertown and Newtown Square road (in fact, the prolongation southwestward of the Roberts road) is in the schists which are exposed in the cut just southwest of the creek, while the gneiss is exposed in a quarry less than a hundred feet north of the road, and thence constantly on both banks very nearly to its source.

Immediately to the south of this road is the large serpentine outcrop (the continuation, I believe, of the La Fayette belt) which contained Moro Phillips' chrome mine, and which extends from east of Darby creek through Marple township. In a cut made for the Chester County Railroad, the gneiss is well exposed a short distance northwest of the serpentine and of Fawkes run, close to the Radnor-Newtown township line.

Mr. Hall maps the whole area from Ithan creek on the east to Crum creek on the west (and beyond it) as far north as Camp run, Reese's run and Central Square as of schists, but the three localities last mentioned, embracing many outcrops, are within this area, and show the rock unweathered and indisputable.

The southerly border of the gneiss is not well defined between

Darby and Crum creeks, but the rock appears on the latter at the mouth of Hunter's run. It is well defined at Ridley creek, close to the serpentine of the Blue Hill Schoolhouse, two miles north of Media. The schists are well exposed southeast of the serpentine, and typical ancient gneiss close northwest of it.

Across the creek from the Blue Hill Schoolhouse, that is on the right or westerly bank, the southerly border of the gneiss forms a high hill very steep on its south side, divided by a branch of Dismal run into two, known locally as Poplar Hill and Round Top; but west of this the border is not clear, exposures being few and poor, and the gneisses of the newer series adjoining it on the southeast being of unusually hard and heavy bedded character, and being possibly altered gabbros. There can, however, be little doubt that it extends south of Howellville, but not as far as Lima, and that before reaching Chester creek the margin turns northward and then eastward (forming the southerly hill of the valley in which the Street road runs) to a point a little east of the Willistown Inn, on the Philadelphia and West Chester road, this hill outlining the southerly branch of the gneiss referred to. From Willistown Inn the southerly edge of the northern and larger branch pursues a west-southwest course to a point north of Oakbourne Station.[33]

[33] On the map in C^5 the gneiss area of Radnor and west is made to end north of Newtown and Central Squares, the schist areas to the east being extended across Newtown and Edgemont to the Chester county line. Southwest of this schist area is represented a large area of the gneiss, extending along Ridley creek from Sycamore Mills to the Chester county line. Westward it forks into three very irregular areas, one trending a little south of west, another southwest and the third south-southwest. But the Radnor gneiss is very conspicuously continued through Newtown and along Crum creek, and the schists and schistose gneisses are equally conspicuous on the south of the gneiss from Sycamore Mills to south of Howellville. Prof. Lesley seems to doubt these areas, for although on p. 91 of his *Final Report* he refers to irregular areas of old syenitic azoic gneiss in Delaware and southern Chester counties, he says (p. 128): "If the distinction between the *older* and the *newer gneiss* be a valid one, the older gneiss seems to disappear from the surface going west from the Schuylkill into Chester county and the newer gneiss seems to occupy the whole field south of the belt of South Valley Hill hydromica slate in Chester."

Within the limits described there is no scarcity of outcrops of the typical rock, but at very few of them can the dip be measured; the following may be selected as typical exposures within the area designated as schists on the map in C^6:—

Cut of the Philadelphia and Delaware County Railroad, northwest of Fawkes run and near The Hunt station.

Road between Newtown Square and Central Square.

Forks of the road .75 m. west of Newtown Square and thence westward on both roads to Crum Creek. On the southerly it is shown in one outcrop,

In the region northwest of Oakbourne, that is near West Chester, there is no longer difficulty in finding the line. The ancient gneiss is exposed a short distance northwest of Westtown School, while the schists are exposed west and south of it. Thence the line curves northwardly and changes from west-southwest to nearly west, the gneiss appearing one-tenth mile northwest of the schoolhouse at Sconnelltown, while serpentine succeeded by schists lies southwest of it.

On the Brandywine the line is close to the forks, and on the right bank is marked by a steep conical hill. It is at this point probably not over half a mile wide. A mile to the westward it forms a separate high ridge known as Brag Hill, separated from the conical hill by the deep valley of a small affluent of the Brandywine; the gap affording an easy passage for the State road.[34] A mile further, near Northbrook, it has become still narrower, occupying but the northerly slope of the hill, with schists and serpentine on both flanks. A mile southwest of Northbrook it appears to end, the schists on both sides uniting and a large outcrop of serpentine appearing.

The limits of the ancient gneiss above given accord closely with those of Prof. Rogers,[35] but as stated differ materially from those in C^5, while in C^4 no distinction is made upon the map between the ancient gneiss and the schists, though they are separated in the text. They differ also from the more recent geological map of the whole State (1893).

Prof. Lesley says of the gneiss "from the gorge of the Nesham-

300′ east of serpentine, dipping S. 25° E. 75°, and in another, 200′ west of the serpentine, S. 50° E. 75° along and south of the West Branch of Ridley creek, north of Howellville.

[34] In C^4, p. 56, it is stated that the area of this gneiss, which is the continuation of that of Delaware county, has a western limit in the vicinity of West Chester, but that a small area occurs at the junction of the East and West branches of the Brandywine, surrounded by mica schists and micaceous gneisses similar to those along the northern edge of the syenite east of West Chester. This does not at all agree with my observations. The northern border is very well defined with numerous outcrops and quarries along Taylor's run to the East branch of the Brandywine and thence through the Worth farm (southeast of serpentine) to the West branch at Seeds Bridge and thence westward across the State road to Northbrook. The southern border passes between the Philadelphia and West Chester road, which is wholly within it from Willistown Inn to West Chester, and the Street road which is in the schist valley. The area appears to narrow rapidly toward the Brandywine, the union of the two branches of the creek being at the border. In this area it is constantly and well exposed.

[35] *Geol. of Pa.*, I, p. 78.

iny to the gorge of the Pennypack it makes what is locally known as the Buck Ridge, with a constant width of two and one-half miles. At Willow Grove it splits, ... its southern fork keeping on as a narrow thread into Delaware county, where it spreads out into three separate areas, the northern one passing on into southern Chester and the southern one into the State of Delaware.''[36]

I cannot believe that Prof. Lesley personally examined this region, for instead of being a narrow thread in Delaware county it there attains its greatest width, more than double its width between the Neshaminy and the Pennypack; the northern area does not extend into southern Chester county, neither does a southern one pass into Delaware, unless the northwesterly extension of the Delaware gabbro be so regarded.

A prominent feature of this belt is its trap dykes. None are large, none can be traced for any distance, the latter fact being due probably to the gneissic rock resisting decomposition equally with the trap, but evidence of its presence is to be found very frequently. In the cut of the Pennsylvania Railroad southeast of Radnor Station two systems of dykes were exposed, one a diorite in narrow veins, dipping about 65° east-southeast, cutting an older granite dipping 60° to 80° west-southwest. Much trap lies on the surface over the ancient gneiss area, and there are numerous outcrops in place—*e. g.*, three-tenths of a mile northwest of Radnor Station (diabase of a reddish tint) on Ithan creek, on the Radnor and Chester road near the old Lancaster road, on Johnston's quarry at Wayne (diabase), near Van Artsdalen's quarry in Bucks county (norite).[37]

Dr. Bascom identified as norite a rock found on the property of Miss Martha M. Brown near Radnor Station.

The Cambrian Sandstone.

Prof. Rogers divided his primal series into three, based upon the exposures in the North Chester Valley Hill, of which the middle member is by far the most uniform and characteristic:—

1. A lower shale, or slate, the lower primal;
2. The middle, or sandstone proper;

[36] *Final Report*, p. 79.
[37] Dr. J. F. Kemp, *Trans. N. Y. Acad. Sci.*, XII, p. 71.

3. An upper, sandy, micaceous, shaly or schistose rock, next below the limestone.

The sandstone formerly supposed to be the equivalent of the Potsdam sandstone of New York is undisputed by all geologists who have examined the region It is abundant and widespread. Lithologically it is remarkably uniform. Its most usual aspect is thus described by Prof. Rogers: "A thin-bedded yellowish-white, very compact rock, presenting in its composition much imperfectly developed feldspar,[38] and showing a tendency to a rhombohedral fracture; . . . . other bands contain likewise many minute partings of crystalline talc, and the surface of the more solid feldspathic beds exhibit very frequently at these partings innumerable minute crystalline specks of pure black schorl."[39]

To this may be added that the rock is often a soft sandstone, while at times very compact and hard, indeed a quartzite, preserving all the other of the above characters; that the tourmaline crystals (of which, when Rogers wrote, schorl was the common name) are not always minute, and that they are generally disrupted.

It should further be noted that at that time the varieties of muscovite of the damourite group were not separated from talc, so that with our present light we should translate talc into damourite, sericite or hydromica in many cases in which Prof. Rogers uses it.

In some portions the markings of *Scolithus linearis* are abundant, particularly west of the Valley Forge Gap. This fossil, though of little value otherwise, distinctly marks the rock as in the paleozoic column, while the unusually definite character of the rock enables us to identify it readily when the markings are absent. This uniform character is remarkable when we consider the numerous outcrops far separated, not only on the strike line but also on the dip. The same rock is described by Dr. Williams as occurring in Maryland.[41]

[38] Kaolinized feldspar.

[39] *First Geol. Survey of Pa.*, I, p. 155, quoted C^1, p. 109.

[40] In the *Final Report of the Second Geol. Survey*, p. 177, it is stated "some of the beds show needles of hornblende and a little crystallized talc." This I think is not the case.

[41] "Quartzite, or quartz schist, . . . such a clearly marked type that it serves at many other localities to fix a definite horizon. There is always present a perfect foliation due to parallel layers of muscovite at varying distances from each other. In these foliation planes there is an abundant de-

The lowest beds, best shown near Willow Grove, are of a conglomerate chiefly of quartz pebbles, united by a siliceous cement. The same rock seems to be poorly exposed westward of Valley Forge.

The Cambrian enters the State near Morrisville, flanking the ancient gneiss on its southeast side, forming a prominent narrow straight hill, in most of its course called (as is also the corresponding outcrop on the northwesterly side of the ridge of ancient gneiss further southwest) Edge Hill, also Rocky Hill. It is here separated from the ancient gneiss by about a thousand feet, chiefly of unctuous variegated clays, which resemble those of the iron ore beds further southwest. On the Trenton Cut-off Railroad, where it is well exposed, it dips N. 50° .W 70° to 80° toward the gneiss.

From this point it continues to Huntingdon Valley, and is exposed on the Neshaminy and in quarries. It seems to narrow westwardly, and at the Pennypack it is not visible; about one mile west of the Pennypack a much overgrown quarry shows indications of it, and masses may be seen in walls in the vicinity; this is immediately north of the limestone of Huntingdon Valley. About four miles further west, it is well exposed in a quarry on the Waverly road near the Limekiln pike, at Waverly Heights, and here is separated from the sandstone northwest of the gneiss by but half a mile; it dips S. 10° E. 70°, S. 20° E. + 70°; S. 25° E. 80°. It is almost identical in aspect with the northerly sandstone, a little more micaceous, a little darker in color, somewhat harder, with cherty layers more abundant, and in this it differs also from the outcrops in the same belt to the eastward. This outcrop is about a mile in length, but is clearly exposed only in this one quarry; it appears to strike into Edge Hill, the topographical continuation of the northerly sandstone hill, more fully described hereafter.[42]

A similar rock, but still more micaceous, and with mica schists interstratified, appears nearly in the line of the strike, about two

velopment of black tourmaline, whose crystals are always transversely broken and their fragments more or less broken as if by stretching."—Geo. H. Williams, *Bul. Geol. So. of Am.*, Vol. II, p. 308.

[42] Prof. Lesley, *Final Report*, I, p. 86, writes of it as forming a low ridge running three miles from Waverly Heights to near Chestnut Hill, but I have been unable to find it beyond the outcrop in the Waverly road about a thousand feet west of the Limekiln pike.

and a half miles to the southwest, on Paper Mill lane north of the Bethlehem turnpike, dipping steeply S. 10° E., while the ancient gneiss, poorly exposed 200 feet north of it, strikes S. 35° W. vertical.

While probable, it is not certain that this outcrop is of the true Cambrian sandstone. If it is, then the adjacent and interstratified mica schists must be of the same age. It may be a rock made by the degradation of the Cambrian and be more recent. Comparing this outcrop with the Waverly Heights outcrop, and that with the exposures near the Neshaminy, we find that the change from Waverly Heights westward is not much if any greater than from the Neshaminy to Waverly Heights.

West of this Prof. Carvill Lewis identified it close to the serpentine, southeast of the gneiss, northwest of La Fayette on the Schuylkill. West of the Schuylkill, in the same line, occur sandy mica schists with rhomboidal jointing, which may or may not represent it. On the Roberts' road south of the Conestoga road, and on the latter west of the Roberts' road (Radnor township) close to the gneiss, a rock appears very closely resembling it; containing, however, no tourmaline. It occurs in narrow beds in the mica schists much as in Paper Mill road; a chert-like quartz accompanies it.

This is the most westerly point at which I have observed any similar rock close to the ancient gneiss on its southeast side, but to the southwest, in Chester county, are numerous outcrops which will be best considered after the more prominent ones to the northeastward.

The Cambrian Northwest of Buck Ridge.

This first appears, as has been mentioned, a short distance east of Willow Grove, where the gneiss forks, and the sandstone appears as the end of a synclinal. This is about ten miles northeast of the Schuylkill. Here the rock is a coarse conglomerate of bluish quartz pebbles in a siliceous paste, followed by the typical rock.

About a mile southwest of Willow Grove, the synclinal of sandstone is in its turn overlain by a synclinal of limestone, the easterly end of the limestone of the Chester-Montgomery valley, dividing the sandstone into a northwesterly and southeasterly arm. The

former is soon covered by the Red Rocks, but appears at intervals. West of the Schuylkill it is very prominent, attaining a height of + 600 feet at Valley Forge, and thence westward forming the North (Chester) Valley Hill.

The rock is well exposed by Valley creek flowing from the Chester Valley through this high hill into the Schuylkill, though the hill dies down to an insignificant elevation eastward within little more than a mile. At this point, as described by Prof. Rogers, the hill appears to be composed, as already stated, of three beds of the Cambrian: (I) a sandy micaceous, shaly or schistose rock (Upper Primal of Rogers') between the sandstone and the limestone of Chester Valley; (II) the sandstone proper, and (III) a shale or slate more argillitic (Rogers' Lower Primal) underlying the sandstone, while underlying the argillitic shale is a conglomerate, poorly exposed, but exactly like that of Willow Grove.

About four miles west of Valley Forge the sandstone appears to end suddenly, on the east side of the gap through which a branch of Pickering creek, rising on the northerly side of the Chester Valley, flows northwardly and then eastwardly into the Schuylkill. In this gap we find no sandstone, but a rock of very different character, probably that mentioned by Dr. Frazer in C[4], p. 272—"A coarse-grained, heavy-bedded rock, called variously in my field notes feldspar-porphyry, conglomerate, granite and heavy-bedded gneiss"—which, from Valley Forge westward, appears to underlie the sandstone with but little, if any, intervening slaty or shaly rock. This rock is well exposed in Williams' quarry on the Phœnixville Branch of the Pennsylvania Railroad, near Aldham Station. It sometimes resembles a pegmatite, often a very feldspathic gneiss, occasionally it is a hornblende or a mica schist or a micaceous gneiss. I have termed it provisionally the Chester county gneiss. North of it is a much harder gneiss, containing blue quartz and closely resembling the ancient gneiss of Buck Ridge, probably the continuation of the northerly arm at Willow Grove, before mentioned.

Further west the upper of these becomes a true mica schist, as on the road south of Caln Meeting-house, and still more markedly north of the Pennsylvania Railroad west of Pomeroy, where the

[43] *Proc. Acad. Nat. Sci.*, 1894, p. 457.

schist contains in small quantity feldspar (probably microclin), coarsely crystalline, tourmaline and garnet, and very closely resembles the mica schists of Rogers' first group. At Pomeroy, just north of this schist, are the great quarries in the sandstone whence has been obtained much of the stone for the foundations of Broad Street Station and other recent structures for the Pennsylvania Railroad. These quarries are in the sandstone proper, dipping S. 35° E. 30° to 50°.

On the map in C[4] this upper schist and much of the true sandstone are colored the same as the gneissic areas on the northerly side of the sandstone, and it is not shown further east than a mile east of Pomeroy, but as extending westwardly, widening rapidly to the Octorara.[44]

On the West branch of the Brandywine the sandstone is met about 200 feet from the railroad, which runs nearly on the strike; it dips S. 25° E. 55°, while on the railroad the schists dip S. 30° E. 50°. About 600 feet further north a harder and less evenly bedded sandstone, some of it quartzite, dips S. 25° E. 50°; two miles north of this is a high bluff of the sandstone in massive beds striking N. 70° E. nearly vertical, at the base of which the creek flows nearly on the strike. On the right bank is the Chester county gneiss.

A half-mile west of the creek the Lancaster pike crosses the railroad and rapidly rises on the slope of the hill; here the schists are again well exposed, as noted by Dr. Frazer,[45] but a careful examination forced me to the conclusion that the apparent inclination of the rock visible close to the railroad is due wholly to creep, as is very evident a short distance northwest where the probable normal dip of S. 35° E. 70° shows, upwards, a northerly dip of loose rock as is so often the case in this sandstone.

Nearly four miles west of Coatesville we reach Pomeroy, and just beyond it Buck Run. Here the exposures are excellent.

[44] Of this, Dr. Frazer says under the heading "West Caln": "The Potsdam sandstone. . . . gradually leaves the contact of the limestone below the borders of this township, permitting an uneven wedge of the older crystalline rocks to intervene between it and the latter in Sadsbury and Valley." C[4], p. 256, and on p. 267: ". . . . from Octorara Creek branch to and beyond Pomeroy. At no place within the distance does the limestone touch the quartzite or sandstone, though removed from it by a belt of varying width, nowhere very broad except at the two points mentioned."

[45] C[4], p. 271.

The sandstone has been largely quarried on both banks of the Run and within 500 feet of the railroad, dipping quite uniformly about S. 35° E. 50° in the four quarries. Included in the sandstone are thin micaceous beds not unlike the schists on the south. On the railroad, southeast of these quarries, and within a quarter of a mile, the mica schists appear; here containing small segregations (?) of microlin(?) and tourmaline, and resembling closely those of Delaware county. One dip was S. 18° W. 75°, others steep S., but there is reason to suspect creep. Within .25m. west, on a private road, about 400 feet north of the railroad, the sandstone is exposed, dipping S. 32° E 80°, succeeded to the southeast by a more schistose variety and within fifty feet a mica schist, dipping irregularly northwest, exposed only in a deep washed-out gutter. The strike is about N. 60° E. The northwest dip is probably due to creep.

About two miles west of Pomeroy is Parkesburg, through the easterly part of which flows a westerly branch of Buck Run. On this, within .1m. of the railroad, is a quarry in the sandstone, dipping S. 15° E. 40°, overlaid conformably by mica schists. About 700 feet about S. 20° E. of this quarry is an exposure of limestone on the south side of the Strasburg road. This road, here running nearly west, forms the main street of Parkesburg, but nearly opposite the railroad station it resumes its west-northwest direction and ascends the hill. Near the foot the mica schists appear poorly exposed, dipping northwest steeply but irregularly, doubtless owing to creep. Following this, about 150 feet of the road is filled with the sandstone dipping S. 15° E. 70°, then sandy mica schists appear with the sandstone for nearly half a mile, the sandstone outcropping at frequent intervals, with a cliff on the northwest side of the road near the summit S. 28° E. 60°. On the summit are no exposures. One mile from Parkesburg the limestone road crosses the Strasburg road. On the former the sandstone is poorly but extensively exposed. West of this to the Octorara I have seen no exposures of the sandstone, but fragments, some very large, are quite common. On the old Valley road northwest of Lenover sandy mica schists appear; no black gneiss was seen. At the Octorara, however, we have a repetition of the section near Coatesville and Pomeroy.

The sandstone is particularly well exposed where the Octorara

flows southward through it. This gap and the adjacent one to the northward through Copper Mine Ridge have been taken advantage of by the Pennsylvania Railroad to pass by easy gradients from the Chester to the Lancaster (Pequea) Valley. The railroad, turning from its nearly west to a northwest course along a shelf quarried out of the precipitous left bank of the Octorara exposes the rocks most clearly. To the southeastward, next to the limestone, there is a somewhat plicated dark-colored mica schist S. 30° E. 80°, perhaps 200 feet in breadth, then the typical sandstone S. 28° E. 72° about 300 feet, then sandstone fragments, and then a bluff of the sandstone, about fifty feet high and a hundred and fifty feet wide, dipping S. 28° E. 70°.[46]

The sandstone continues west of the Octorara as a narrow but high and conspicuous hill, bounding the limestone valley on the north; as in Chester county, its crest is nearly straight, S. 60°–70° W., and for several miles almost level about 200 feet above the Octorara or 660 feet above tide. The hill seems to be composed almost wholly of the sandstone, the Chester county gneiss forming the floor of the valley on the north and the hills further north to Copper Mine Ridge. The rock is abundantly exposed, occasionally, but not frequently, in such manner as to show the dip beyond doubt. The bearing of the Valley road is almost coincident with the strike. About two miles west of the Octorara, just west of the road to Steelville (Chester county), a dark mica schist appears on the north side of the road with the sandstone with some

[46] In Prof. Lesley's *Final Report*, Vol. I, p. 177, this ridge is apparently confused with the parallel ridge to the north, "Copper Mine Ridge." It is there stated "In the North Valley Hill, the gaps of the East and West Brandywine and at Gap Station show the beds to be about 100′ thick." Gap Station, however, is on the northerly side of Copper Mine Ridge, a parallel northerly outcrop of sandstone, separated from the North Chester Valley Hill by more than two miles of gneissoid rocks, and according to my observations this separation continues far into Chester county, Copper Mine Ridge ranging eastwardly to within a hundred yards of the West branch of the Brandywine near Wagontown as a distinct narrow ridge of the typical sandstone, evidently referred to in C^1, p. 262.

It may also be observed that on the map in C^4, the yellow color, which is stated on p. 160 to be "confined to the quartzite and sandstone beds alone, and does not include the underlying much weathered feldspar porphyries, conglomerates, etc., which (following Prof. Rogers) he regards as part of the Potsdam or primal formations No. 1," is broadened to four miles, viz.: from Compassville to Parkesburg, thus connecting the sandstone of Copper Mine Ridge with that of the North Valley Hill. I was unable to find such connection, for a broad belt of the "feldspar porphyries, etc.," intervenes, as stated by Rogers, I, p. 84, etc. (quoted C^4, p. 163, etc.).

interlaminated dark mica schist on the south, strike of road and rock N. 70° E.

The further discussion of this ridge will be found in connection with the limestone of this portion of the valley.

North of the North Valley Hill, in the vicinity of the branches of the Brandywine, are three other outcrops of the sandstone, as noted by Prof. Rogers.[47]

The southernmost ranges a little north of east from west of the Lancaster county line south of Compassville to a point within .2 m. northwest of Wagontown. It forms a low ridge conspicuous north of Stony Hollow Schoolhouse, and seems to end in a very narrow outcrop on the farm of Abraham Bubaker, just north of a steatite outcrop. It appears to be the continuation of the sandstone of Copper Mine Ridge in Lancaster county, the southerly boundary of the Pequea Valley limestone.

The middle outcrop is much more prominent and is locally known as the Baron Hill. It ranges in an east-northeast direction from the Lancaster county line, or west of it to the East Branch of the Brandywine, at Cornog's Station. In most of its course it is a high hill, with comparatively steep slopes, and throughout the greater part of its course entirely in forest, thus making a prominent feature of the landscape. North of Martin's Corner it is, by barometer, 850 feet above tide, the valley south of it of ancient gneiss being 750 feet and north of it 690 feet, limestone.[48]

The northernmost outcrop forms the Welsh Mountain, on the summit of which is the Chester-Lancaster-Berks county line. It is also the watershed between the Delaware and the Susquehanna, with an elevation of 850 to 1,000 feet above ocean level.

Returning now to Willow Grove, we may trace the southeasterly arm of the sandstone synclinal southwestward. As far as the cross-

[47] I, 177, quoted C^4, pp. 154, 155.

[48] On the map, C^4, the sandstone area north of Martin's Corners is represented as two miles wide, extending of nearly that width to the West branch, there cut off by the ancient gneiss, with two outlying islands of this sandstone to the eastward. With this my observations do not agree. North of Martin's Corner it is not much over a quarter of a mile in width. Along the West branch it is conspicuously exposed between a point .5 m. below Ferndale Station and Brandamore Station, dipping S. 25° E. 50° E. Northeast of this it continues unbroken as a narrow, mostly wooded hill to the East branch, near which it seems to terminate in the ancient gneiss. A road on or near the summit affords a series of very beautiful views Brandywine Manor is on this hill.

ing of the Northeast Pennsylvania Railroad the conglomerate continues with the typical standstone overlying it. From east of Weldon to west of Edge Hill village the sandstone forms a prominent hill, and probably the highest ground of the vicinity, known as Edge Hill, giving name to many places in the neighborhood. The North Pennsylvania Railroad levels are Chelten Hills 190, Junction Northeast Pennsylvania Railroad 254 (259 ?), Edge Hill 293, Camp Hill (the northerly ancient gneiss) 178. The levels of the Northeast Pennsylvania Railroad crossing the sandstone about a mile north of the North Pennsylvania Railroad are Junction North Pennsylvania Railroad 259 (254 ?), Summit 342, Willow Grove 259.[49]

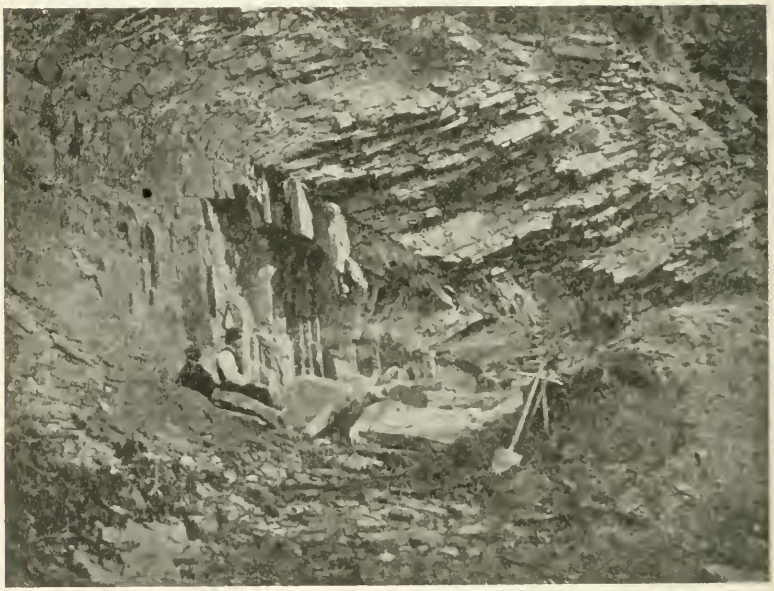


FIG. 1.—Cambrian Sandstone, Edge Hill, Pa.

At Edge Hill village, where the sandstone is crossed by the North Pennsylvania Railroad and the Limekiln turnpike, it is well exposed in a cut about thirty feet deep, and in quarries which show very plainly the "creep" to which the upper part of this rock

[49] These (mean ocean) levels are taken from Tables 60 and 62 in *Second Geol. Survey of Pa.*, Levels above Tide N.

has been subjected, shown in fig. 1, a photograph taken by Mr. John Coates Brown. Its strike is about N. 55° E.; it is nearly vertical, probably 85° S. E., and is very regular. In a quarry close to the Northeast Pennsylvania Railroad its dip is S. 30° E. 65°, hence toward the ancient gneiss; these dips are well below all possible creep.

It is here that the sandstone southeast of the ancient gneiss appears a half-mile to the southeastward, with the gneiss intervening, but not prominently. It is not improbable that the two areas were once connected at this point over the gneiss, if indeed they were not over a much more extended area.

West of this, Edge Hill, as has been stated, continues topographically to the Wissahickon, but the geological formations strike through it westwardly, that is strike about S. 60° W., while the bearing of the hill itself is about S. 40° W., so that soon the Edge Hill sandstone forms a separate, slightly divergent hill, known as Barren Hill. It crosses the Wissahickon on the place of Mr. John T. Morris, where it is well exposed. It continues probably from Barren Hill to the Schuylkill, though not well exposed except close to the latter at Spring Mill, where it appears to dip S. 45°, though the exposure is not entirely satisfactory. There is limestone here ± or about 500 feet northwest of it.

So far no slates or schists are visible in its vicinity, though some beds of the sandstone are very micaceous and rather quartz schist than sandstone. The strike from the Spring Mill outcrop carries it into that portion of the Schuylkill which flows about N. 70° E. along the base of the ancient gneiss from Conshohocken to Spring Mill. On the westerly bank the flanking gneiss, Rogers' Altered Primal, and the limestone are well exposed, but the sandstone is not distinctly visible, and its place appears to be taken by mica schists, some garnetiferous, not unlike those between the Cambrian and the limestone on the north side of the Chester Valley, the Upper Primal of Rogers already described. These are on the south side of the narrow valley between the gneiss on the southeast and the hydromica schists on the northwest, a narrow but typical straight limestone valley known as Cream Valley. As a prominent valley it is five miles in length, ending at Wayne, but with two drainage systems; the upper three and a half miles draining by Gulf creek through the Gulf (a gap in the northerly

hill), the lower mile and a half directly to the Schuylkill.[50] The divide is low and from the high hills on each side hardly noticeable. While the prominence of the valley ceases at Wayne, a depression follows the line of strike to the West Branch of the Brandywine and beyond, as will be more fully described when considering the limestones.

On the northerly slope of the ancient gneiss the sandstone appears at intervals. In the *Final Report* (I, p. 174) this is discredited, but I have given[51] my reasons for reiterating these occurrences as they seem to explain the structure without the need of a fault. I may repeat briefly that the sandstone may be observed of typical character and in the same relation to limestone at distances from the Schuylkill of one and a half, two, two and a half, two and three-quarters, three and a half and four miles. It appears to be interstratified in mica schists, but all the exposures are poor. It is certainly very narrow.

West of Wayne the schists continue, but the typical rock is absent or concealed. The latter is not improbable, as the line of strike is in comparatively low ground with few outcrops between the gneiss and the hydromica; these outcrops being of mica schist, serpentine, or diabase trap. In western Chester county, however, it again appears near the Poorhouse quarry, and still more extensively near Doe run, as mentioned in the discussion of the limestones of that region.

The locality near the Poorhouse quarry limestone is Hayes' whetstone quarry, a mile nearly west of the limestone. It is of the typical rock, overlaid by sandy mica schists and underlaid immediately by the same with more compact and heavy-bedded schists to the northwest. It dips S. 30° to 50° E. 20° to 25°. It is in Newlin township, close to the West Bradford line. Thirty or forty years ago there was a considerable output of whetstones from this quarry, as I am informed, by Mr. William M. Hayes, owner of the Hayes farm, who was then engaged in their manufacture.[52]

[50] F. Bascom, Ph.D., *Am. Geologist*, Jan. '97, XIX, No. 1, p. 56.

[51] *Proc. Acad. Nat. Sci.*, December, 1892, p. 445.

[52] In C^4, p. 314, this quarry seems to have been confused with a quarry of dark-green chlorite schist used in the neighborhood for flagstone. The latter quarry, known as Fulton's, is on the Speakman farm, about a mile west of the Hayes quarry.

Southwest of the Poorhouse quarry is a series of limestone quarries (Embreeville, Pierce, Edwards, Guest, Doe run), but there are no exposures of the sandstone until the Guest quarry is reached. West of it and east of Doe run it is found abundantly. A detailed description will be found in the discussion of the limestones.

Southeast of the ancient gneiss ridge and of the outcrops just described, which seem to belong to the series northwest of it, the gneiss itself ending near Northbrook and west of Chester creek, are several outcrops of the sandstone accompanied by limestone, both having been quarried, the limestone very extensively and for at least a half a century. In view of this well-known fact, it is strange to find the contrary stated in the *Final Report of the Second Survey.*[53]

Of these outcrops, the easternmost is in Thornbury township, Chester county, one mile north-northwest of the Delaware county line, where the typical rock, interstratified in schists, appears on the road next northwest of the Wilmington road, half a mile south of the Street road, on the farm of John Wyeth. The rock is in place, but the exposure poor. There is an outcrop of limestone about three miles south of this, Bullock's quarry in Birmingham township, Delaware county, but the closely adjacent rocks are not visible.

About a mile southwest of this it is exposed on the Wilmington road, dipping about southeast 30°, with mica schists apparently conformable both above and below it. A half-mile southwest it is exposed in a quarry about three-quarters of a mile north-northwest of Dilworthtown. The dip is N. 35° W. 80°; nothing but the sandstone is visible. Half a mile nearly south from this quarry, many loose masses are visible in the road which leads to West Chester, next southwest of the Wilmington road, where the road from Dilworthtown to Birmingham Meeting-house crosses it. About three-quarters of a mile nearly west of the quarry just mentioned and less than a half-mile northeast of Birmingham Meeting-

[53] "There is no sandstone, no limestone to be found in the Atlantic coast country southeast of the Buck Ridge gneiss, except just at its southern edge. The country between it and the Delaware river is occupied by a great series of azoic rocks, . . . among which not a single stratum of sandstone or limestone can be found." *Second Geol. Survey of Pa., Final Report*, I, p. 86.

house is limestone exposed in a quarry and dipping S. 40° E. 50°. No other rock appears in place, but thousands of schist fragments lie to the southeastward of the limestone; a quarter of a mile south, schists dip S. 30° E. 30°.

Along the Brandywine the rocks are well exposed; the limestone is visible in Harvey's quarry, at Brinton's Bridge, about a mile above Chadd's Ford, and the sandstone ought to be visible, but it is not. But under the limestone of Huey's quarry, about three-quarters of a mile east-northeast of Brinton's Bridge, there is exposed a quartz schist dipping N. 60° E. 20° under the limestone, and further westward the sandstone is exposed abundantly close to the Red Lion Hotel in East Marlborough township and thence westward and two miles south in Kennett township, east, north and west of Kennett Square.

If the outcrops mentioned be plotted, it seems clear that they cannot be ranged in one or two synclinals, unless very undulating. It seems equally certain that no succession of anticlinals can be made out of the Brandywine section. The country, except along the large streams, is covered with mica schist and gneiss fragments, with occasional outcrops of the same rock in place with pyroxenite and gabbro. The peculiar sandstone, where it occurs, is of typical character, the adjacent schists both above and below the sandstone closely resembling Rogers' Upper Primal of the North Valley Hill, and there seems no marked distinction between those above and below.

It may be briefly stated that in Chester county, south of the Chester Valley, there are several outcrops of the typical rock. So far as can be observed, all dips are southeast under southeast dipping limestone, with possibly one exception to be hereafter noted (Taylor's quarry).

1. One mile west of the limestone of the Poorhouse quarry, dipping S. 30° E. 25°, with schists dipping about the same above and below (Hayes' whetstone quarry, already mentioned), the limestone dipping S. 40° E. 5° to 25°.

2. West of Logan's quarry, west of Unionville, dipping probably S. 75° E. 30°, with schists S. 55° E. 70° above and S. 55° E. 55° below; the limestone about S. 40° E. 50°, with garnetiferous schists S. 30° E. 45° overlying.

3. Northwest of Eli S. Bailey's quarry and southwest of

Logan's quarry are two well-exposed outcrops about 150 feet apart, with mica schists above, between and below, all dipping about S. 40° E. 30°.

4. A half-mile northwest of the Guest quarry, West Marlborough, dipping southeast probably 45° and less, the limestone dipping gently southeast with sandy mica schist between, also probably the same bed, .2 miles west of the quarry.

5. Two hundred feet west of the Enos Bernard quarry south of Doe Run village, dip not visible, the limestone dipping either 30° or 80° nearly west; also about .2 miles east of the Enos Bernard quarry; fragments only visible.

A little over a mile south-southwest of the Enos Bernard quarry and northeast of Marlborough Hall Schoolhouse sink-holes indicate underlying limestone, while in the east and west road close sandstone is shown by numerous loose masses.

6. The most important belt stretches from east of the Red Lion through London Grove village to west of Chatham, bordering on the north the Street road limestone outcrops. Near the Red Lion it dips S. 25° E. 15° to 50°, mica schists underlying. West of Taggart's cross-roads S. 5° E. 15° to 20° toward the limestone.

At London Grove it is well exposed in a quarry .3 miles southwest of the meeting-house, S. 35° E. 30°, with sandy mica schist overlying and a harder schist underlying.

7. South of Lewis Bernard's quarry it is poorly exposed at the northern foot of the hill between Bernard's and Story's quarry.

8. Southeast of Story's quarry it is clearly exposed in a quarry about .2 miles east of West Grove Meeting-house, overlying mica schist and dipping S. 50° E. 20° under the limestone of the Avondale Lime and Stone (formerly A. G. Hughes & Co.'s) quarries, northwest of Avondale, in which the limestone dips S. 40° E. 20° and less, with mica schists overlying.

9. North and west of Kennett Square and also east of it, bordering the Kennett limestone on the north.

Reviewing these sandstone outcrops in western Chester county, and taking a section line about S. 15° E. from Honeybrook township to London Britain township, we find the following succession:

North	Red sandstone and trap,	Turkey Hill, Forest Hill.
1.	Limestone,	Churchtown, Lancaster county.
	Sandstone,	Welsh Mountain.
	Ancient gneiss and igneous rocks,	Southern part of Honeybrook township.
2.	Limestone,	Southern part of Honeybrook township.
	Sandstone,	Baron Ridge.
	Ancient gneiss (gabbro?),	South of Martin's Corner.
3.	Sandstone,	North of Wagontown.
	Chester county gneiss,	Wagontown and south.
	Ancient gneiss,	Siousca Station.
	Chester county gneiss.	
4.	Sandstone.	North Chester Valley Hill.
	Mica schist,	Caln Meeting-house.
	Limestone,	Chester Valley.
	Hydromica schist,	South Valley Hill.
	Mica schist,	South of Modena.
5.	Sandstone,	Southeast of Doe Run village.
	Mica schist,	Not over 500 feet wide.
	Limestone,	Guest quarry.
	Mica schist,	Not over a mile wide.
6.	Sandstone,	Northwest of Logan's and Bailey's quarries.
	Mica schist,	Not over 500 feet wide.
	Limestone,	Logan's and Bailey's quarries.
	Mica schist,	About a mile wide.
7.	Sandstone,	London Grove.
	Mica schist.	
	Limestone,	Street road line.
8.	Sandstone(?),	South of Bernard's.
	Mica schist,	South of Bernard's.
	Limestone,	Story's quarry.
9.	Sandstone,	Road Avondale to West Grove.
	Limestone,	Hughes quarries.
	Mica schist and gneiss.	
10.	Sandstone,	In same valley north of limestone to the eastward.
	Limestone,	Watson & Jones' quarry, Avondale.
11.	Limestone,	Nevin's quarries.
	Mica schists.	
12.	Limestone,	Eastburn quarries.
	Mica schists.	

(The brackets connect those outcrops which appear related.)

It will be seen by this table that we have eight certain lines of outcrops of the sandstone, with two uncertain and eleven of limestone.

North of the Chester Valley, the limestone is close to and north of the sandstone, while in the valley and south of it the limestone is usually close to and south of the sandstone. Among the whole, in this section, there is not one from which we can with certainty infer an anticlinal or synclinal structure, except perhaps in the limestone of the Nevins' quarries and in the easterly part of the Doe Run Valley. If the first is synclinal, the northerly sandstone leg is concealed by the Red sandstone. At the second, rocks apparently identical with those elsewhere referred to the ancient gneiss lie closely adjacent to the limestone on the north, and with some undoubtedly igneous rocks separate it for at least two miles from the northerly Cambrian sandstone, while the southerly sandstone forms a high hill and is the nearest visible rock, perhaps 500 feet being concealed. South of this sandstone hill is again the ancient gneiss, including possibly some areas of the Chester county gneiss, extending about two miles to the Wagontown-Copper Mine Ridge sandstone hill, followed by about two miles of the Chester county gneiss, with possibly some areas of ancient gneiss, extending to the North Valley Hill. The sandstone in this hill was believed by Prof. Rogers[54] to be not over a hundred feet in thickness, and its apparent width to be due to compressed anticlinals and synclinals, but I think the evidence of these inconclusive.

The sandstone, however, dips under the limestone, a thin stratum of mica schist intervening from Caln Meeting-house westward, and does not rise on the southerly side of the Chester Valley, as it does on the northwest. There is, however, nearly south of the King of Prussia, and thence westward for a mile or two and north of Paoli, a narrow outcrop of sandstone with iron ores. The best exposure was on the Trenton Cut-off Railroad, north of Paoli.[55]

Prof. Rogers writes of this as occurring also east of Downingtown, and further says:[56] "In the vicinity of Coatesville and west of it this well-marked rock . . . . projects conspicuously in

[54] I, 174, quoted C⁴, pp. 147–148.
[55] *Proc. Acad. Nat. Sci.*, 1891, p. 119.
[56] *First Geol. Survey of Pa.*, I, p. 166.

rugged outcrops at the entrance of the numerous ravines and gorges, thirty or forty feet thick.''

I have tried in vain to find these outcrops, not only by personal examination, but also by inquiry of observing residents, who have assured me that there is no sandstone visible in that vicinity on the north slope of the South Valley Hill.

This sandstone, while at the locality near Paoli resembling that of the North Valley Hill, is so very limited in area that the probabilities are that it is a more recent rock overlying the limestone. It lacks the characteristic tourmaline crystals.

South of the limestone is a mile of the hydromica schists, followed by three miles or more of mica schists, many of them heavy-bedded and hard, followed by the sandstone, and then softer schists and limestones, the dips in the hydromica being steep to the south in its northerly part, mostly vertical in its middle and southerly portions, and the mica schist and almost all other rocks from it southward dipping toward the southeast with angles rarely above 35°. It is true, however, that at this limestone outcrop feldspar and hornblende gneisses appear close on its northerly side further eastward, and that still further eastward the sandstone appears on its southerly side.[57]

Still going southward, and passing a region almost without outcrops but with a soil suggesting the schists and containing schist fragments, we find outcrops of the sandstone, followed by a narrow stratum (300 feet to 500 feet) of mica schist, and then the limestone of Logan's and Bailey's quarries South of this, mica schists, at times garnetiferous, extend for a mile, followed by the extensive outcrops of the sandstone at and near London Grove, overlying which are mica schists, and over them the limestone of the Street road line. At one locality south of and near Bernard's limestone a small outcrop of sandstone appears, but the exposure is so poor that not much reliance can be placed upon it. South of it is a hill of mica schists and about a mile south of Bernard's the limestone of Story's quarry, south of which are very clear outcrops of the sandstone, followed by the limestone of the Avon-

[57] About three quarters of a mile south of the Embreeville outcrop of this belt is a stratum of white quartzite with tourmaline shown in loose masses only, but in quantity. While unlike the sandstone this may possibly represent it and make the structure synclinal.

dale Lime & Stone Co., which dips very gently south and is overlaid by garnetiferous mica schist. This is followed by the limestone of the Watson & Jones quarry, Avondale, almost certainly of the Kennett series, and if so, further east undoubtedly underlaid by the sandstone well exposed.

The "Potsdam" is stated by both Dr. Frazer[58] and Prof. Chester[59] to underlie the limestone of extreme southern Chester county and northwestern New Castle county, Del. I was unable to find any exposure of sandstone either north or south of Nevins' quarry. The limestone of this quarry being clearly anticlinal in structure,[60] the sandstone, if it occurs to the southeast, can hardly underlie the limestone.

In the schists of Rogers' first and second groups are occasionally and abundantly sandy schists which have much the aspect of these schists associated with the type rock, but the latter rock itself is absent. The outcrops in Thornbury, Birmingham, near Doe Run, in London Britain and in East Marlborough show conclusively that the type rock is underlaid and overlaid by mica schists not infrequently garnetiferous. There seems, therefore, no reason to doubt the conclusion of Prof. Rogers and of Dr. Frazer, that these schists belong in the paleozoic column, as certainly do those north of Pomeroy and Parkesburg.

The argument in Cream Valley is not less conclusive. Here we have east and west of the Schuylkill a succession of rocks uniform, except that a mica schist in the west takes in part the place of the typical sandstone two miles to the eastward. Besides this, we have in this very schist further west a chert-like quartz and the typical sandstone at several localities and in abundance, associated as usual with limestone. It is reasonable, therefore, to believe that the mica schists of Cream Valley are likewise Cambrian. These schists we can follow with constant outcrops in a narrow line to a point near West Chester, where they widen rapidly and again show limestone. Further west they still widen, the limestone becomes more frequently exposed and again we find among them the typical sandstone. But here apparently the same schists may be traced southward without a break, until they unite

[58] C⁴, 328.
[59] *Proc. Acad. Nat. Sci.*, 1884, p. 239.
[60] C⁴, 327.

with those of East Marlborough, Kennett, etc., which is another confirmation. That there are repetitions, in spite of the uniform southeasterly dip, is most probable, but the data are too meagre to define them.

Again, the mica schists of the Huntingdon Valley must be of Cambrian age or more recent. They very closely resemble those of Cream Valley. But if all these schists are of Cambrian age, why should greater antiquity be claimed for the very similar rocks of the Philadelphia newer schists and gneisses ?

Along the north slope of the North Valley Hill, at several localities, is a very compact sandstone which I have not seen in place, though often local outcrops show a similar rock. This particular rock is more quartzite than a sandstone, weathers of a light yellow color and not infrequently shows white-ribbon-like markings. These are curved, branched, swell out and contract, and seem to indicate an organic origin.

Limestone.

In discussing the limestone outcrops in this region it will be convenient to divide them into groups, ranging along west-southwest lines, based upon their geographical position, following the usual strike of the rocks:

1. That of Van Artsdalen's quarry, Bucks county.
2. Those of the great Chester-Montgomery (Plymouth) Valley.
3. Those of Edge Hill, Flourtown, Spring Mill, West Conshohocken, Cream Valley, Cope's quarry northwest of West Chester, those of the valley stretching southwestward from the East branch of the Brandywine above Copesville to Embreeville, and of the Guest quarry.
4. Those of the Doe Run Valley.
5. That of the Huntingdon Valley southeast of the ancient gneiss.
6. Those of Pocopsin township, Logan's quarry and Elisha Bailey's quarry, in Chester county.
7. Those in West Thornbury, Birmingham and northeastern Pennsbury township, Chester county, and Birmingham, Delaware county, and westwardly much more largely exposed to the south of the Street road westward of the Red Lion Hotel, toward West Grove.

8. Those in the valley through which the Baltimore Central Railroad runs; that is, in central Pennsbury, Kennett, northern New Garden and London Grove townships, Chester county.

9. The small areas on the southerly line of New Garden and London Britain townships, Chester county, and those of New Castle county, Del.

10. Several small outcrops in northern Chester county.

The first, that of Van Artsdalen's quarry in Southampton township, Bucks county, is a small isolated outcrop in the ancient gneiss of a highly crystalline limestone much mixed with other minerals, of which the variety made this locality famous, but, like many others, the quarry has not been wrought for years. It appears to be clearly within the ancient gneiss and to have no relation to any other outcrop, no other limestone having been exposed in any part of the fifty lineal miles of this gneiss exposed in this region. Near by is a dyke of norite. Prof. Kemp suggests that it may be an included piece of limestone caught up in a flow of igneous rock.[61] It is much folded and contains considerable graphite; the other minerals most prominent are pyroxene and wernerite.

II. Limestone of the Chester County.

The second is by far the most important, and has been the object of the most study. The valley underlaid by the limestone extends unbroken from Willow Grove on the northeast into Lancaster county on the southwest, where, according to the observations of Dr. Frazer,[62] it joins the great outcrop of the Lancaster and Pequea Valleys.

In Montgomery county its length is about fifteen miles, in Chester thirty and in Lancaster ten, a total of fifty-five miles. In width it varies greatly and suddenly, the greatest being about two miles and the least a quarter of a mile. It is well exposed in numerous outcrops, and has been extensively quarried. It dips with much uniformity steeply to the southeast, and, while local deviations are common, no systematic undulations appear. Compressed anticlinals have been exposed—*e. g.*, in the cut of the Schuylkill Valley Railroad below Potts' Landing, and in that of

[61] J. F. Kemp, *Trans. of the N. Y. Academy of Natural Sciences*, Vol. XII, p. 77.

[62] CCC., pp. 75, 76.

the branch of the Pennsylvania Railroad from Chestnut Hill to the Trenton Cut-off near Camp Hill. Of these the former is instructive. The limestone here formed a high bluff, the base of which was the left bank of the Schuylkill river. In a bench cut into the limestone the Norristown Railroad was located, and there was exposed a series of strata dipping quite uniformly to the southeast. More recently, the Schuylkill Valley Railroad, running parallel with the former, was forced to quarry more deeply into the hill, when it appeared that some of the apparently parallel strata formed opposing legs of an anticlinal. It seems to be admitted that this structure is common, though not usually apparent, and that the limestone is not nearly so thick as would be inferred from its general width.

West of the Schuylkill river this valley is remarkably straight, especially on its south side. Its streams rarely flow for any great distance along the axis of the valley, indicating that the present courses of the creeks and rivers were established long before erosion gave us the present contour lines. This apparently erratic flow is emphasized by the present contour, for it is possible for an observer to stand at points overlooking the valley, with its high and well-marked bounding hills, and see seven streams leave the floor of the valley and flow, toward the east-northward, toward the west-southward, through the apparently impenetrable walls, forming gorges with precipitous sides, rising at times three or four hundred feet above the valley.

In its northeast part there seems to be no question about the relation of the limestone and the adjacent rocks, for we have apparently without doubt a basin of the peculiar sandstone, the Primal of Prof. Rogers, the Potsdam and No. 2 of the Second Survey, now generally believed to be Cambrian, underlying and surrounding the limestone. This sandstone, at times concealed by the newer Red Rocks on the northerly side, seems clearly to bound it on the north to the westerly termination of the valley at Quarryville, Lancaster county, forming usually a high hill.[63]

In the portion of the valley east of the Schuylkill river, known as the Plymouth Valley, the limestone has been and is largely

[63] As more fully referred to in the discussion of sandstone, Dr. Frazer believes an area of older rocks to intervene between the sandstone and the limestone from Pomeroy westward. C⁴, pp. 256–267.

quarried, formerly as a flux for iron furnaces, as well as for building uses. The iron furnaces having been abandoned, it is now quarried for the manufacture of lime, for railroad ballast and road material, and for concrete, except a comparatively small amount used as building stone. Near the Schuylkill, on both sides of the stream, a slaty limestone, containing much quartz, mica and graphite, has been largely quarried for foundation stone. For large buildings in Philadelphia it has been used probably more than any other stone, as it can be obtained in masses of any desirable size, with easy and smooth fracture, or more properly cleavage, in one direction. At the Schuylkill the limestone is probably as wide as at any point, extending from Swedesburg to the northerly part of Conshohocken, a distance of about two miles, the river flowing nearly on the line of dip. The northerly boundary is the Red sandstone, quarried in and about Norristown. At Norristown the Cambrian sandstone is reported to appear in limited areas, but I have not been able to find the typical rock at the Schuylkill.[64] West of the Schuylkill, however, are two prominent hills, one near the river northwest of the Trenton Cut-off Railroad, the other two miles to the westward, northwest of Henderson Station. Exposures in these hills are poor, but abundant fragments and one or two quarries indicate on the side toward the limestone a fine-grained mica schist, and next northwestward a conglomerate very closely resembling that underlying the sandstone to the northeastward. In one quarry near Bridgeport the dip is S. 10° E. 50°; in one near the northwest end of the hill nearest the river S. 50°.

The limestone on the river bank dips S. 10° to 20° E. 30° to 60°. It seems probable, therefore, that this is the basal conglomerate of the Cambrian, the typical sandstone being absent or concealed.

The southerly boundary is a prominent hill of hydromica schist. About a mile west of the Schuylkill the valley is suddenly and greatly narrowed by the widening of the hydromica schist hill from about four-tenths of a mile at the river to over a mile and a half two miles to the westward.

A little over two miles west of the river is Henderson Station, geologically important from the discovery by Mr. Martin B.

[64] C[6], p. 74.

Stubbs in Shainline's quarry of fossils in orbicular quartzite, identified by Prof. Heilprin as *Lituites orthoceras* (*Gyroceras*), *Maclurea* or *Pleurotomaria*, and *Murchisonia*, of which specimens are in the collection of the Academy. Unfortunately, all the masses found were loose in the decomposed limestone soil overlying the common limestone. A rock very closely resembling that in which the fossils were found occurs in great abundance in the railroad cut west of Henderson Station, here also probably not in place, and almost certainly in place about a mile to the eastward, where the highway was shifted northward at the time of the construction of the Trenton Cut-off Railroad. At this locality, notwithstanding the rock was largely exposed, no trace of fossils has been discovered. A similar rock occurs eleven miles further west in small quantities and in loose masses only, near Sidley Station on the Phœnixville Branch of the Pennsylvania Railroad, but no fossils have been found. It occurs also on the west side of and near the Schuylkill below Norristown, and also in loose masses but very abundantly about a mile and a half northeast of Norristown, at which place some of the quartz crystals were arranged in cylindrical forms, giving rise to a newspaper paragraph that the rock contained fossil Indian corn. This rock resembles the calciferous sandrock of New York.

The hill near Henderson Station in which this rock occurs is skirted on the north by the Swedesford road, while the Trenton Cut-off Railroad and the Chester Valley Railroad cut its southerly base. The northernmost rock, shown in fragments only, is a conglomerate of blue quartz resembling the basal member of the Cambrian. Next, also only in fragments, is a schist or slate like that exposed in the Valley Forge gap. This slate seems to form the summit of the hill. The southerly portion is of clay and gravel, chiefly of quartz pebbles, but with some pebbles which apparently were of gneiss, now much decomposed. In this, as far as can be seen, occurs the orbicular quartzite, of which the masses appear not to be rounded. In the bottom of the cut a large mass of limestone appears. The hill near the Schuylkill presents much the same features. Near the King of Prussia the area of Red sandstone which overlies the limestone near the Schuylkill, from east of Norristown northwestward, suddenly narrows, exposing the limestone floor nearly or quite to the river at Port Kennedy, where

the unconformable contact of the two is well shown. Here the high North Valley Hill of Cambrian sandstone begins, and in a distance of about a mile rises to a height of over 500 feet, cut, however, a mile beyond by the deep gorge of Valley Creek at Valley Forge. From the longitude of Valley Forge to that of Frazer, about seven miles, the valley continues with a width of about two miles wholly of limestone, except small areas of a hydromica schist apparently interbedded. At this point the North Hill, ranging from 550 feet to 670 feet above tide, with but a slight gap at Diamond Rock, suddenly ends, and a north-and-south valley intervenes with an elevation of about 380 feet. Here, on the north edge of the valley (near Devault Station on the Phœnixville Branch of the Pennsylvania Railroad), a branch of Pickering creek rises and flows northward and eastward into the Schuylkill, while close by is the source of the Valley creek, which flows southeastward, then eastward, then north through the Valley Forge gap into the Schuylkill. In this valley of the branch of the Pickering creek there is not a trace of the sandstone, though but a half-mile to the eastward or westward it is prominent. In the Chester valley in this vicinity are large limestone quarries, wrought chiefly for building lime, the largest being those at Cedar Hollow, at the foot of the hill, about .75 mile southeast of Devault Station, and those of the Knickerbocker Co., about 1.75 miles southwest. From this point westward the valley is narrower, averaging about a mile in width, though the rock margins are rarely to be seen, being deeply buried, especially on the north side, so that while the valley is well defined, it is but a supposition that the base of the hill is the border of the limestone.

Opposite Glen Loch is a watershed across the valley and the highest ground in it, by barometer about 380 feet above tide, from Frazer as datum 490 feet. Bacton is 365 feet, Sidley 370, Devault 375, Aldham (descent into Pickering Valley) 305. This watershed and the gap just below make an easy gradient for the Phœnixville Branch of the Pennsylvania Railroad.

In the vicinity of Glen Loch large marble quarries were formerly wrought and also mines of limonite iron ore. Near Bacton Station are large deposits of kaolin near the abandoned Trimble Iron Mine, famous as a locality of wavellite and cœruleolactite.

In the valley, between the longitudes of Berwyn and Glen

Loch, are outcrops of a schist, whether interbedded in the limestone or folded is not certain. On the Schuylkill section we find very slaty limestone (Bullock's quarry, etc.), and also, in the limestone, beds not over two feet thick of a hydromica schist or slate. North-northwest of Berwyn about one mile a similar slaty rock forms a hill on the farm of Mr. A. J. Cassatt, and thence westward appears at intervals. At Cassatt's dips, not very satisfactory, were toward the north S. 10° E. 60°, and towards the south S. 10° E. 90°. About 600 feet west-southwest of this is a quarry in limestone, with dips of S. 30° E. 80° on the northerly side and middle and S. 20° E. 70° on the southerly side. The easterly face of this quarry showed a small compressed synclinal, and the slate is not far from the line of this synclinal. To the westward it again appears just south of the large quarry at Howellville. A little less than a mile west of Howellville and about a mile north of Paoli Station it forms a prominent hill. On its southerly slope a slaty limestone dips S. 25° E. 85°. In the road which passes through a small gap in it the rock itself is not exposed, but limestone on both sides, dipping S. 20° E. 70° to 90°. The slate itself is exposed in a small quarry on the hill, and appears to dip S. 10° to 20° E. 80° to 85°. On the north flank of this hill the Chester Valley Railroad passes through a cut in limestone S. 20° E. 75°.

Five hundred feet westward the slate hill is again prominent, with a small limestone quarry on its north flank. The hill is quite regular for about a mile, showing one gap through which a small stream flows northward. It ends a little east of Cedar Hollow Station, Chester Valley Railroad, with limestone on the north flank dipping S. 20° E. 75° and S. 30° E. 60°.

Nearly three miles to the westward, on the left (north) bank of Valley Creek, and less than a half-mile northeast of Mill Lane Station (Chester Valley Railroad), is a high hill of the same schist. This, being wooded, is a prominent feature in the landscape, especially looking from the line of the Pennsylvania Railroad, which, opposite, descends the northerly slope of the hydromica schist ridge and continues westwardly near its foot, affording a succession of fine views. In this hill I found no outcrop of the slate which could be satisfactorily measured. At one place the strike appeared to be N. 60° E., and the dip probably southeast. There is limestone on the north side within 500 feet of the schist, and on the south side

within twenty feet, dip S. 30° E. 65°. That on the south has been very extensively quarried by William B. Irvine and Andrew Carty (Knickerbocker quarries). The dip is about S. 30° E. 60° in the quarries.

North of this hill limonite pseudomorphs after pyrite occur loose in the soil. Rarely a portion of the enclosing rock is attached. It is a damourite schist. They occur also in the schist of the hill east of Cedar Hollow Station.

In the Knickerbocker quarries a narrow vein was filled with fine crystallized, crystalline and fibrous aragonite.

Nearly due south of this, and less than a half-mile north of Frazer, hence very near the south margin of the valley, is a small hill of similar schist north of the Lancaster turnpike with limestone on both sides within 500 feet. It appears to dip S. about 30° E. about 80°, the limestone S. 25°–35° E. 55°–60°. This, of course, is not at all in line with the outcrops near the Chester Valley Railroad, but nearly on the strike of this outcrop at Glen Loch, a mile and a half further west, is another on the farm of Mr. William E. Lockwood, forming a low hill striking more southwest than the trend of the valley. I found no good exposures.

At Catanach's quarry, near Cedar Hollow, a gravel of quartz pebbles overlies the limestone; a similar gravel occurs south of the Valley Forge gap, on the road to Devon. About four miles west of Downingtown the valley narrows to about a half-mile. At Coatesville it is crossed by the West branch of the Brandywine; thence westward it becomes still narrower.

At the west boundary of Chester county it is crossed by the Octorara creek and is again of greater width, about a half-mile. In Lancaster county it continues just as clearly defined as in Chester, though the floor of the valley is higher and the slopes of the bounding hills less steep. These hills are just as in Chester county, hydromica schist on the south, Cambrian sandstone and schists on the north.

Dr. Frazer's tracing of the probable connection of the limestone of this valley with that of the Lancaster Valley is one of the most valuable contributions to the geology of this part of the State. The identification of the limestone of these two valleys carries with it the identity of the bounding sandstone.

The discovery of fossils in the Lancaster limestone[65] seems to prove that part at least of the Lancaster limestone is Cambrian, and hence that part at least of that of the Chester Valley must be of the same age.

There seeming to be no doubt that the easterly end of this limestone is a synclinal near Willow Grove, I carefully examined the westerly termination. As I deem the structure not certainly made out, I desire to place my observations on record, in hope that future work by abler hands may solve the problem.

Going westward by the main route of travel, the Pennsylvania Railroad, the casual traveler passes out of the Chester Valley almost without noticing it, and is apt to regard the next valley on the north as its continuation; whereas, on approaching the Octorara, the railroad bends quite abruptly to the north, and ascending the left bank of the Octorara a very short distance, passes by the gap of that stream through the sandstone of the North Valley Hill, crosses the Octorara to the town of Christiana, then passes over two miles of gneissoid rocks and then through Copper Mine Ridge (Cambrian sandstone) to Gap Station, on the southeasterly edge of the Pequea Branch of the great Lancaster Valley.

Beginning at Midway, now the western edge of Coatesville, and near the point at which the Lancaster turnpike leaves the valley and takes a more northerly course, the Valley road[66] is an important highway through Quarryville to the Susquehanna. For so hilly a region it is remarkably free from steep hills, and yet deviates very little from a straight line. Running westward along the foot of the North Valley Hill, it crosses the Octorara about a mile and a half west of Atglen, and then ascends the hill to its summit, which is here very narrow, so that in passing along the road the adjacent valleys, both north and south, are visible, the elevation being about 665 feet or about 200 feet above the creek.

The descent of the floor of the limestone valley from Parkesburg

[65] *Olenellus* and *Obolella*, one mile northeast of Gap Station. C. D. Walcott, *Am. Jour. Soc.*, Vol. XLVII, Jan., 1894.

[66] Now often called the Old Valley road, to distinguish it from a comparatively short highway also called Valley road, laid out more recently from Parkesburg to Atglen, and lying in the valley about half a mile south of the Old Valley road, which runs along the North Valley Hill near its base.

westward to the Octorara is quite gentle, as is also its ascent to the westward of that creek.[67]

The floor of the gneiss valley on the north rises much more rapidly, so much so that at about five miles west of the Octorara the gneiss rises to the level of the sandstone, the northerly valley ends and thence westward the drainage is, as in Chester county, from the gneiss region across the valley southward, except the first creek, Valley run, which flows southward through the North hill into the valley, which it follows eastward to the Octorara, and except also the Quarryville drainage which is northwestward. The ridge trends S. 60° W. for two and a half miles, then S. 70° W. Throughout this distance the typical Cambrian sandstone is shown by fragments, by the sandy soil and in occasional outcrops in place. One dip, at a good exposure, half a mile from Christiana, was S. 20° E. 65°. Two miles beyond, the strike is N. 65° E., dip uncertain. On the rise of the hill beyond this, and about 100 yards west of the road to Steelville, the rock is exposed on both sides of the road, which is almost exactly on the strike S. 70° W. On the north side it is typical Cambrian sandstone, on the south the same with thin layers of dark sandy mica schist. This continues for nearly 500 feet, and then, near the top of the hill, the rocks are less exposed, but there are mica schist fragments on both sides. About .25 m. west of the road to Steeleville the road and hill trend S. 75° W., quite level, to and beyond a road leading north to Smyrna. East of this cross-roads the sandstone, unusually hard and massive, approaching quartzite, is visible in large loose masses—one of several tons weight, but not certainly in place. The soil is very sandy. At the cross-roads the sandstone outcrops

[67] In C^4, p. 17, it is stated that the Pennsylvania Railroad crosses the Chester Valley west of Caln, and gradually rises upon the north slope to "The Gap," in Lancaster county, and that from Pomeroy westward the floor of the valley rises rapidly into Lancaster county, but not so fast as the railroad. This does not accord with my observations.

Tested by barometer the levels of Pomeroy and the Octarara creek, here the boundary between Chester and Lancaster counties, are nearly the same. The railroad rises from Pomeroy westward to the watershed between Buck Run and the Octorara, but immediately descends as shown on p. 18 where levels are given, Pomeroy 483′, Parkesburg (2 m.) 537′, Summit 562′, Penningtonville (5 m. from Parkesburg) 500′. In *Levels Above Tide*, Christiana, in Lancaster county, about half a mile from the Octorara, is given about 491′. Moreover, the drainage of the valley from a point two miles west of Pomeroy is westward into the Octorara. The railroad, however, as above stated, leaves the valley before entering Lancaster county.

S. 20° E. 75°; .2 m. west of the cross-roads is a quarry in the sandstone on the north side of the road S. 30° E. 35°. It is near this that the valley on the north is almost obliterated by the rise of the floor, and here also the Valley road begins to leave the summit, but the deviation is slight. The road now crosses the Sadsbury-Bart township line, and soon crosses a small creek about sixty feet below the summit. This is Valley run, which flowing southward from the gneiss into the valley flows eastward through it to the Octorara.

West of this creek the road rises gently about thirty feet in .3 m. to a cross-roads (north nine miles to Williamstown). The road continues to rise, as does also the hill and the floor of the valley. In the latter are abandoned iron mines (between Bart Post-office and Nine Points). No fast rock is visible along the road, but much quartz in fragments, some white, some rusty and some smoky, closely resembling that occurring north of the same hill in Chester county.

After a descent of about seventy feet the road crosses the creek which drains the Gap nickel mine. Here the sandstone is not visible, but north of the road and on the left bank of the creek is a bold bluff of dark mica schist with quartz, showing minor plications and dipping N. 35° W. 80° to 85°. The road rises beyond this creek about seventy feet, and then descends fifty, to cross the westerly branch of the last-mentioned creek; beyond this the road ascends ninety feet, and then descends slightly to cross a small creek. This is about a mile and a half east of May Post-office. Here the schist is again exposed, together with a large amount of loose trap, a fine-grained olivine diabase.

Beyond this the road passes through a very soft unctuous micaceous rock, very fragile, resembling that which occurs with the iron ores.

Two-tenths of a mile west of the trap masses of hard Cambrian sandstone become very abundant; the fences are made of it, and great quantities lie in dumps, together with a few masses of trap. About .1 m. beyond a road goes south into the valley. Opposite this road, about five hundred feet north of the Valley road, is a precipitous cliff, about fifty feet high, of the typical sandstone. It is much jointed, very compact and hard, approaching quartzite. The base of this cliff is 100 feet above the road.

From this westward the sandstone is abundant to May Post-office near which is trap, but insignificant in quantity compared with the outcrop a mile further east. West of this is a gradual descent for three-quarters of a mile, the road bearing S. 80° W., and then a gradual descent of about one hundred feet in 1.25 miles S. 60° W. to Quarryville.[68]

South of the valley, in Lancaster as in Chester county, ranges the straight and little-varying South Valley Hill of hydromica schists. South of Quarryville its elevation is 150 feet to 170 feet above Quarryville Station, which, taken at about 488 feet would give an elevation of from 638 feet to 658 feet.

From points near the summit a bird's-eye view of Quarryville and the adjacent country may be had, beautiful in itself and instructive geologically. Looking eastward the valley is seen as far as the eye can reach, bounded northward by the Cambrian sandstone hill. Westward, high, apparently irregular hills close the valley and end the view. Northward, or rather north-northwestward, stretches the irregular valley of the Big Beaver creek, bounded east and west by high hills, but northward permitting the view to extend to the great Lancaster limestone valley.[69]

Examining more closely, these eastern and western hills are seen to send forth promontories overlapping each other, as pointed out by Dr. Frazer, so that while the valley is continuous it is tortuous, as is most evident to a traveler upon the railroad which follows it.

[68] C⁴, p. 114, "Prof. Frazer shows that the valley limestone lies on Potsdam sandstone from the Schuylkill to near Coatesville; that here, for a short distance, thin mica schist layers come in between the limestone and the sandstone (these would be Prof. Rogers' Upper Primal slates), and that west of Pomeroy and all the way to Quarryville, in Lancaster county, no sandstone underlies the limestone; but, instead of that, the limestone rests upon feldspathic gneiss beds, gneissoid mica schists, etc. (these would be Prof. Rogers' Lower Primal slates)." But, so far as I have seen, nowhere east of Coatesville is the typical sandstone much better shown than in the gap of the Octorara, thence westward for a mile and at the locality mentioned near May Post-office, and it is as well shown for the greater part of the intervening distance as it is north of the valley in Chester county.

[69] Dr. Frazer well describes the westerly ending of the valley: "The north boundary wall sweeps up to the northwest, leaving the level limestone land between itself and Quarryville. The south wall sweeps around Quarryville and almost closes up the valley a short distance due north of that town and west of the Mount Holly schoolhouse" (CCC, p. 75). The trend of the westerly hills is, however, nearly north-northwest, bordering Big Beaver creek, a branch of which rises a little south of Quarryville and flows nearly north-northwest and then northwest, so that the angle of the two valleys is much more than a right-angle.

Bearing in mind Mr. Hall's demonstration of the synclinal structure of the easterly end, "where the Potsdam sandstone borders it on the south, and where its round basin-shaped east end is perfectly manifest" (C⁴, p. 116), and his further demonstration that in the middle of this half-round basin-shaped end lies the northeastern end of the hydromica schist of the South Valley Hill, I sought for evidence of the structure of the hill at this westerly end. Exposures of the hydromica schist are few and poor—one .4 m. south of Quarryville was S. 10° E. 40°; further south strike N. 50° E., dip uncertain; .5 m. dip southeast; .7 m. S. 50°; .8 m. S. 20° E. 70°; 3 m. S. 30° E. 65°. This was near Mechanics' Grove; three miles northwest of Mechanics' Grove and southeast of The Buck, S. 20° E. 45°.

About a mile northeast of The Buck a fence was seen, composed of a quite hard plicated gneiss, containing white feldspar and quartz beds or veins. This appeared to be of quite limited extent and was the only exception to the hydromica. About two miles nearly north of The Buck the road descends eastward a long hill of the schists, which near the top dip west 10°, further down S. 40° E. 20°; these were soft, even-bedded and sectile. This was about three miles a little north of east of Rawlinsville. Then descending a small branch of the Pequea Creek, the same schists were very largely exposed, dipping S. 80° W. ± 10°. This was in the vicinity of Smithville, and on the road from Rawlinsville to the Spread Eagle. Eastward toward New Providence no exposures were seen until about a mile west of New Providence, when much loose quartz appeared, and then a mine of limonite iron ore and, a quarter of a mile further, a hard limestone, N. 30° W. 35°, with minor plications. This point is probably three miles at least north of a line in the prolongation of the southerly side of the sandstone of the North Valley Hill. Northwest of New Providence, about a half mile, a plicated limestone dips south to S. 10° W. ±16°. About 500 feet east of New Providence a schistose limestone coming out of the quarry like flagstones, but some portions plicated, N. ± 40° W. 10° to 20°.

About 500 feet north by west of New Providence limestone dips N. ± 40° W. ± 45°. About 1000 feet further, N. 20° W. 30° to 40°. About a half mile south of New Providence, in a quarry, strike N. 60° E., dip in one place 70° northwest, in an-

other, inaccessible, it seemed from a distance to be gentle southwest. On the railroad .6 m. south of New Providence the limestone is just visible, but at about one mile, in quarries, it is from 0° to S. 15°. This is about 2.25 miles northwest of Quarryville. Nearly north of Quarryville is Hawksville, and here limestone outcrops N. 45° W. 35°. On the Valley road east by north of Quarryville .25 m. limestone dips 0, further east, northwest gentle, then sandy mica schists shown in fragments only, and at one mile Cambrian sandstone, abundant, the road leaving the valley and ascending at a very acute angle the southerly slope of the North Valley Hill.[70]

The road north from May Post-office, that is, near the westerly edge of the tableland, ascends the valley of a small creek flowing southward across a broad tableland, continuous northward from the North Valley Hill, and free from steep slopes, except on its westerly border, where it ends abruptly at the valley of Big Beaver creek in the series of promontories before described.

One-tenth mile north of May Post-office the sandstone is in great quantity and extends for nearly a mile. Here a road goes east to Georgetown, and a dark sandy schist appears. About 1.3 miles from May Post-office another road goes east to Georgetown, and at 1.4 a road west to Camargo; between these the only rock is quartz in loose masses. It does not resemble that of the Cambrian sandstone. At about two miles another road goes west to Camargo, and a schistose sandy rock dips S. 70° W. 15°. This, I think, is the Cambrian. In the vicinity the loose masses are of the typical rock.

A little beyond this is the Bowery Church, the road attaining its greatest elevation, 810 feet. North of the church it descends into a small valley which heads perhaps .2 m. to the eastward and descends to the valley of Big Beaver creek, on the north side of Camargo. Near New Providence the easterly branch of the creek, which flows through this side valley, is joined by the south branch (not shown on the map C^3) which, heading in the limestone southeast of Quarryville, flows northwestward. The valley of

[70] In the map of Lancaster county (C^3), the Valley road is represented as within the limestone area four miles east of Quarryville. I think, however, it leaves the limestone three miles further west, as around May Post-office the Cambrian sandstone is very abundant.

this south branch is taken advantage of by the Quarryville branch of the Reading & Lancaster Railroad, which passes through this rugged region by easy grades, and with very moderate cuts and fills, though with little straight track.

In the valley of Big Beaver creek (south branch) the limestone seems to be almost, if not quite, continuous. There is, as Dr. Frazer notes, one narrow ridge .2 miles northwest of Quarryville, which appears to cut it off. This is of hard heavy-bedded mica schist, and is the ridge on which Hawksville is situated, though at Hawksville limestone appears, dipping N. 45° W. 35°. The schist is gnarled and twisted. The dip appears to be steep, but I could obtain no satisfactory measurement. It is not over .25 mile wide at the creek.

The fact that the hydromica schists of the south hill occupy the region in the strike of the valley west of the limestone at Quarryville seems to negative the theory of a fault along the south side of the valley bringing up the schists from below.[71]

My view of the westerly end of the valley would be that on the north the gneiss and mica schist (Rogers' Lower Primal) and the Cambrian sandstone end in a high tableland with promontories projecting into the Big Beaver valley, but that other areas of the sandstone overlie the gneiss and mica schist east of the Big Beaver valley, but none of these rocks appear west of it near Quarryville; that the limestone, with a general westerly dip of low intensity, sweeps northwest along the Big Beaver toward the Lancaster valley; the hydromica schist, widening first southward, widens west of Quarryville northwardly overlying the limestone.

III. Limestone of Flourtown, Cream Valley, Etc.

The third series should really not be separated from the second, for there can be no question, I think, that they are identical: the Spring Mill sandstone and limestone being the southeasterly legs of the synclinal of which the limestone of Plymouth and the sandstone of Cold Point are the northwestern,[72] as shown on Mr. Hall's map, C^5, for we can trace the limestone of the Chester-Montgomery valley around the northern end of the hydromica to the Schuylkill and find it in its turn surrounded by the Cambrian

[71] Dr. Frazer, *Proc. Am. Ass. A. S.*, 1884, p. 394.
[72] *Final Report*, I, p. 174; C^4, 303.

sandstone. Their supposed absence westward has led to several theories.[73]

As far as to the Schuylkill this structure seems to be admitted.[74] It is west of the Schuylkill where the diversity of opinion is manifest, and this, I believe, arises from a failure to recognize the topography of the region and the rocks which are actually there.[75]

A glance at the topographical map of Philadelphia and vicinity of the U. S. Geological Survey will show that west of and near the Schuylkill there are, southeast of the great Chester Valley, three subordinate valleys, all trending west-southwest, and separated by high hills of hydromica schist. The northwesterly two

[73] Prof. Lesley's *Notes of the Geol. of the Schuylkill River*, 1884, p. 6.

[74] "Its acknowledged synclinal structure in Montgomery county, where the Potsdam sandstone borders it on the south, and where its round basin-shaped east end is perfectly manifest." C^4, p. 116.

If tradition may be trusted, the source of the great spring which gives name to Spring Mill is in the northerly leg of the synclinal though the spring itself is in the southerly valley. The following facts I obtained in 1893, from the well-known Dr. Hiram Corson, of Plymouth, he being then over ninety years of age. There was a large sink hole near Plymouth meeting-house filled up when the Plymouth railroad was built. When he was young it was reported and currently believed that chaff thrown into this sink hole was ejected at Spring Mill.

On the property of Mrs. Hovenden near the meeting-house was a well fifty feet deep, at the bottom of which was a swiftly flowing stream.

A quarter of a mile west of this was a sink hole in a quarry (since filled up) at which the sound of running water could be clearly heard.

The spring is said to flow twenty-two hundred gallons per minute. The limestone area, southeast of the hydromica, seems insufficient to yield so great an amount while the northwest area is very much greater. So far as I have been able to ascertain no large spring rises in the northwest valley.

[75] In C^4, p. 127, it is stated: "The southerly border of the limestone belt crosses the Schuylkill at Spring Mill and follows Gulf Creek into Chester county a little less than a mile south of the Baptist meeting-house"—presumably the Great Valley Baptist Church, 1.5 miles north-northwest of Devon Station. In Prof. Lesley's summary of the arguments for and against the synclinal structure of the Chester Valley (C^4, pp. 116 *et seq.*) he seems to regard the topographical valley alone, and to esteem the limestone and sandstone outcrops southeast of the hydromica schist as of no importance because they are so much smaller than those on the northwest.

But in the quotation from p. 127 he clearly recognizes the limestone at Spring Mill as the southerly border and traces it along Gulf Creek, but no one who has visited the locality can possibly unite the limestone of Spring Mill with that on Gulf Creek near its mouth. The identity of the Spring Mill limestone with that of West Conshohocken cannot be doubted, while between the latter and the limestone on Gulf Creek, between the Gulf and its mouth, intervenes the hydromica schist hill just as it does east of the Schuylkill between the limestone of Spring Mill and that of the Plymouth Valley. It is possible, however, that the outcrops on Gulf Creek west of the Gulf may be intended, for these are the continuation of the Spring Mill limestone, but if so, several miles of the schists separate them from the limestone of the Chester Valley near the Great Valley Baptist Church.

are soon lost on the hydromica schist highland, the southeasterly continues along the southeast foot of the hydromica schist hill. The Gulf Creek, rising in the southeast valley about 1.5 miles south of the Great Valley Baptist Church, follows it to the Gulf, then turns abruptly north through the hill by a deep and precipitous gorge, and then follows the northwest foot of the southeasterly hydromica schist hill and along the southerly edge of the Chester Valley limestone to the Schuylkill; this hill is here quite narrow, the strike line of the two northwesterly hills being occupied by limestone continuous with that of the Chester Valley, but a mile or two to the westward the three hills unite to form a tableland nearly two miles wide southeast of the church. Some of the difficulty may arise from the fact that the Schuylkill river, flowing on the line of dip across the Chester Valley or Plymouth limestone and the hydromica past the upper part of Conshohocken, turns almost at right angles, along the base of the opposite ancient gneiss ridge and on the line of strike of the Spring Mill-West Conshohocken limestone for over a mile, when it resumes its southeast course and passes through a gap in the ancient gneiss hill.

On the left bank, just above this gap, is Spring Mill. The limestone appears on the left bank at and above Spring Mill, and to the southeast of it the sandstone. Southwest of these outcrops the limestone and sandstone appear to be covered by the longitudinal flow of the river, so that while the river is but about a quarter of a mile wide the distance between the outcrops at Spring Mill and West Conshohocken is about one and a half miles.

On the right (west) bank the limestone appears in considerable quantity in the long, straight, narrow Cream Valley and supplied the Merion furnaces with flux during their whole existence.

West of West Conshohocken there are but three actual outcrops of the limestone of this belt in Montgomery and Delaware counties, viz., at Gulf Mills, at Stacker's or Brooke's quarry, .25 mile west of the Montgomery-Delaware county line and on the farm of Peter Pechin, one-half mile northwest of Radnor Station. Limonite iron ore, as usual, overlies the limestone and was extensively mined east of the Gulf and less largely on Pechin's farm, north-northwest of Radnor Station and Fenimore's, a half-mile further west, and also south of Devon Station, Chester county. On and west of Pechin's there are sink holes near the Eagle road, be-

tween the King of Prussia road and that leading to St. David's Station, and in Wayne, due north of the Presbyterian Church and south of the Eagle road, the last now filled up, also about a half mile northeast of Sugartown, Willistown township, Chester county.

The above limestone outcrops are, respectively, .1, 1.25, 2.5 and 3 miles from the Schuylkill ; the sink holes 3.4, 3.6, 3.7, 4.1 and 10 miles.

As already stated, the sandstone is well exposed on the left bank of the Schuylkill, about 500 feet southeast of the limestone, dipping S. 40°. On the right or west bank the sandstone is not visible, its place being taken by, or it being concealed in, mica schists, which border the limestone on the southeast and which also appear between two adjacent outcrops of limestone. The southeasterly limestone dips about S. 30° E. 80°; the schist S. 28° E. 74°, the northwesterly limestone about 80° northwest.

Five miles from the Schuylkill the valley is no longer prominent, its floor having risen to 400 feet above tide, almost to the level of the adjacent hills, nevertheless a depression can be traced southwestward, in which north of Sugartown there is the sink hole above mentioned, but for nearly sixteen miles no limestone is visible.

North of West Chester and about fifteen miles from the Schuylkill the valley is once more well marked, its floor occupied in part by the garnetiferous schists, its southeast boundary the ancient gneiss hill on which West Chester is situated, and its northwest the South (Chester) Valley Hill, precisely as near the Schuylkill, except that here the mica schists make the southerly part of the hill and that a ridge of serpentine appears in the valley. In this valley, about a mile and a half northwest of West Chester, at Cope's, the limestone once more appears at the surface, accompanied by the garnetiferous schists which adjoin the limestone of West Conshohocken and appear at close intervals the whole distance and which to the westward include the sandstone.

The schists here appear between two outcrops of limestone about 100 feet apart, the northwesterly very slightly exposed, showing now only one mass of limestone, dipping apparently gently to the southeast or toward the larger quarry and under the schists.

The southeasterly quarry has been wrought in a stratum of limestone only thirty feet to sixty feet in thickness, and for a

distance of about 200 feet. Both walls are visible. The northwesterly is of garnetiferous mica schist, or gneiss, including masses of feldspar, exactly resembling that of Cream Valley, Radnor. It dips N. 45° W. 65°, the limestone in contact with it N. 55° W. 60°, but they appear to be strictly conformable and the slight difference is probably due to irregularity of the surface measured. The southeasterly wall is a hard schistose gneiss, containing much feldspar, some apparently porphyritic, and some an aggregate of crystalline feldspar. The limestone, however, appears to rise in an anticlinal over this and to dip gently southeast beyond it, but, apparently, of a thickness of but a few inches. The gneiss surface toward the quarry is curved, but in the straight part toward the southwest end dips N. 30° W. 65°, while over it the limestone appears with a northwest dip of not over 20°. The appearance further east is as if the limestone was folded completely over this gneiss. This limestone is not far from the strike of the serpentine, which, however, does not make its appearance.

About a mile west of Cope's the East branch of the Brandywine flows in a nearly southeast direction across the strike of the rocks, and at the crossing of the creek by the Strasburg road is Cope's Bridge, or Copesville. About a quarter of a mile above is a small valley in the hard mica schists and gneiss. Above this for .3 mile is a coarser gneiss and hornblende schist, dipping S. 30° E. 60° to 70°, followed by another valley seemingly in prolongation of a limestone valley west of the Brandywine about to be described. In the line of the upper valley the creek changes its direction for nearly a half-mile from southeast to nearly northeast. The limestone of Cope's quarry appears to be in this intermediate hill, not far from the strike of the southerly valley, and it does not appear in either valley east of the creek.

In the northwesterly valley we find the spangled mica schist full of garnets, forming the northwest hill and dipping very clearly and regularly S. 45°. In the southerly hill no exposures were noted except along the Brandywine, but the loose rocks are hard feldspar and hornblende gneiss. The Conshohocken trap dyke (diabase) passes near the summit of this hill on its southeasterly slope, but reaches the Brandywine only about .1 mile above Cope's Bridge, the southerly valley not extending over .3 mile from the Brandywine.

Opposite the northerly valley, on the right bank of the Brandywine, but a little higher up the stream, a well-marked limestone valley stretches west-southwest. Southeast of it is the high hill of the schists on which Marshallton is situated. The first quarry is that of George March, about .8 mile northwest of Copesville. It is wholly in compact limestone, dipping quite regularly S. 30° E. 20°. Over it are quantities of loose mica schist, with some large masses about 100 feet south of the quarry. About .3 mile north-northwest of the quarry the nearest rocks on that side appear on a lane on the Ingram farm. They are hornblende and feldspar schistose gneiss, striking N. 80° to 90° E., and dipping 60° and upwards nearly south, or toward the limestone. As stated, the valley is here well marked, the north and south hills rising to a height of 150 feet or more. A section of this point shows continued widening of the schists, which form the Marshallton hill.

The gneisses and schists here, as pointed out by Dr. Frazer, bear much resemblance to those of southern Delaware county,[76] and this not only in their essential constituents, but also in their containing both blue and gray kyanite. The more micaceous schists are nearly a mile in width to the border of the ancient gneiss, which is a little north of the Fairview Schoolhouse, the serpentine being here, as at Taylor's mill, close to the old gneiss. The harder and more feldspathic and hornblendic rocks north of the limestone are succeeded northward by mica schists to Hawley's mill, a mile north of the limestone, the dips being to the southeast, averaging below 45°, and are there succeeded by the hydromica schists nearly 90°, but about .25 mile above Sugar's bridge there is a small outcrop of very sandy schist closely resembling those occuring with the typical sandstone.

A mile northwest of this on the farm of Wilson Young's estate, and in the valley of the creek flowing into the Brandywine at Hawley's mill, is a small outcrop of dolomite containing much green talc or chlorite. The country west of the Brandywine is much more hilly than that to the east, a succession of hills trending about S. 70° W. rising 250 feet above the adjacent valleys.

About .4 mile south-southwest of March's quarry is a smaller one on the farm of Moses Woodward, almost obliterated, mica schist fragments abundant on the south, but no good exposures. Just

[76] C⁴, p. 61.

beyond this there is a low watershed in the valley, the westward drainage being into the West branch through Broad run. On this run, about .7 mile from March's, was Moses Bailey's quarry.[77] This quarry is quoted from Rogers (C^4, p. 70) as being the most easterly. It is probable the more easterly quarries were not opened when Rogers wrote.

On the Strasburg road, a short distance east of this quarry, is a large outcrop of pegmatite, or coarse granite, with garnetiferous mica schist very close to it to the northwest, both near the floor of the valley, but probably on its southeast side, while on the northwest the hill is composed of schistose gneiss dipping steeply northwest and forming a high hill. Immediately south of the limestone quarry are garnetiferous mica schists, and in them was found a large and distinct pebble of the ancient gneiss. This corresponds closely with the similar occurrence in the Stacker-Brooke quarry in Radnor township.

Three-quarters of a mile west-southwest is the most prominent quarry of the region, known as the Poorhouse quarry. It has been wrought nearly northeast into the side of a comparatively steep hill and wholly in limestone, except the top of the north west end. The limestone is hard and highly crystalline, but full of small irregular cavities in which occur crystals of pearl spar, quartz, chesterlite and, more rarely, rutile. On the northwest side, near the entrance, the dip is clearly S. 40° E. 45°, but on the same side of the quarry further in (northeast) the dip seems to decrease rapidly to about 5° southeast. The back of the quarry (northeast) shows sixty feet or seventy feet of limestone overlain by ten feet to twenty feet of mica schist, perfectly conformable though showing in one place a breaking down, due probably to a sink hole in the limestone. The dip of this northeast side is about 5° southeast, though there is in it a distinct small anticlinal forming an arch probably twenty feet wide fifteen feet high, but apparently merely local and not disturbing the upper strata. The nearest rocks observed to the southeast are hard porphyritic schistose gneisses on the left bank of the West branch of the Brandywine, west of Glen Hall Station, Wilmington and Northern Railroad, nearly horizontal, succeeded by fine-grained and plicated schists,

[77] Boardsley run, C^4, p. 40, and Boardley run, p. 70, Broadley in the index, are probably typographical errors for Broad run.

which at the Glen Hall bridge dip N. 70° W. 10° to 40°. This dip is distinct, but most of the rock appears to have an irregular waving gentle southerly dip. The nearest northwest are on a road bearing north-northwest on the west side of the quarry, and about .3 mile from it, where a cut shows decomposing schists and gneisses with thin strata of quartzite, the bedding or cleavage quite regular S. 40° E. 50°, becoming steeper southwardly.

From Cope's to the Poorhouse quarry, there seems to be a very decided difference in character between the rocks above and those below the limestone. Assuming those dipping under it to be really below geologically, as seems almost certain, we have the same succession as has been observed in the dolomites of New York island, the underlying rocks being much harder and containing hornblende and feldspars in considerable quantity, while those overlying are comparatively soft very schistose rocks, without hornblende and much less feldspar.[78]

About a mile nearly west of the Poorhouse quarry (probably a little less than a half-mile on the dip line) is the Hayes' whetstone quarry, of typical Cambrian sandstone interbedded in sandy mica schists. The sandstone dips S. 30° to 50° E. 20° to 25°, or toward the limestone.

This is the first clear outcrop of the sandstone on this line west of Wayne, though one specimen was found loose not far from the Cope quarry, and a quartzite with tourmalines occurs near the limestone quarries east of the Poorhouse quarry, but here the sandstone is on the northwest side of the limestone with moderate southeast dips, whereas near the Schuylkill it is on the southeast side.

Standing on the hill above the Poorhouse quarry, a fine view of the Brandywine valley is had. To the eastward and westward it is narrow, with high steep bordering hills, but southwest it is broad and flat, with the creek forming an S bend and flowing 1.5 miles in a lineal distance of .5 mile. Further southeast a depression leads from Embreeville southwestward. At Embreeville, one mile

[78] "As Prof. Dana has noted (*Am. Jour. Sci.*, III, Vol. XXI, p. 439), the beds underlying the limestone of New York county are highly quartzose, while those overlying them are chiefly micaceous. Throughout Westchester county south of the latitude of Sing Sing the writer has found this lithological difference to prevail." Merrill, *Metamorphic Strata of Southeast New York*, *Am. Jour. Sci.*, III, XXXIX, p. 387.

S. 50° W. from the Poorhouse quarry, is a small limestone quarry in which the dip is S. 45° to 50° E. 60°. Less than 200 feet northwest of this, mica schists, garnetiferous and spangled, are well exposed, dipping regularly S. 45° to 55° E. 30° to 45°, hence clearly under the limestone. In these schists is a dyke, bed or vein of a partly kaolinized feldspar.[79] To the southeast are gneisses dipping S. 50° E. 55°. A mile and a half S. 60° W. from the Embreeville quarry are the quarries of Pierce and Edwards, near the Green Valley Baptist Church, the limestone dipping S. 50° E. 35°, and .5 mile further S. 60° W. Job Hayes' quarry near the south line of Newlin township, the rock dipping S. 30° E. 35° The adjacent rocks are not exposed. In almost the same direction 1.25 miles further are the extensive Guest quarries, spoken of by Rogers as Connor's quarry. Rogers gives the dip as southeast, and mentions the white sandstone as dipping to the southeast north of it with the older primal slates also dipping southeast beyond.[80]

My own observations give varied gentle dips in different parts of these quarries to the southeast, southwest and northwest, but the general dip is probably to the southeast quite gentle. In the immediate vicinity small loose masses of the typical sandstone are abundant, while large flat slabs of it are in use as flagstones at the farmhouse north of the quarry, but I was unable to ascertain exactly whence they were obtained. About 700 feet north of the quarry mica schists dip S. 30° W. 20° toward the quarry. Iron ore occurs on the Doe run road about .7 mile southeast of the quarries, and also at Pennock's iron ore mines .5 mile a little east of north. Here considerable ore (limonite) appears to have been taken out. On the Doe run road a half-mile northwest of the quarry, and thence southward, the typical sandstone is very well and largely exposed, forming a hill about seventy feet high northwest of the Guest quarry. An exception to any other locality in the whole region, it is here much plicated. It dips southeast 20° to 30°, with sandy mica schists immediately southeast of it dipping 15° S. E., and mica schists just west of it dipping S. 70° W. 45°. About half-way between the sandstone and Guest's quarry decomposing mica schists dip about 45° S. E. South of the

[79] Soda-Orthoclase, T. C. Hopkins, *Journ. Franklin Inst.*, CXLVII, p. 13.
[80] *First Geol. Survey of Pa.*, I, 230. Quoted C[4], p. 72.

quarry are no exposures, but the soil is full of fragments of mica schist and gneiss.

This is the last quarry that can be certainly referred to the series mentioned. Prof. Rogers, after discussing this series from Broad run to the Guest quarry, says: "The furthest opening in the limestone in this synclinal is that of Baker's quarry, half a mile east of the west line of West Marlboro' township."[81]

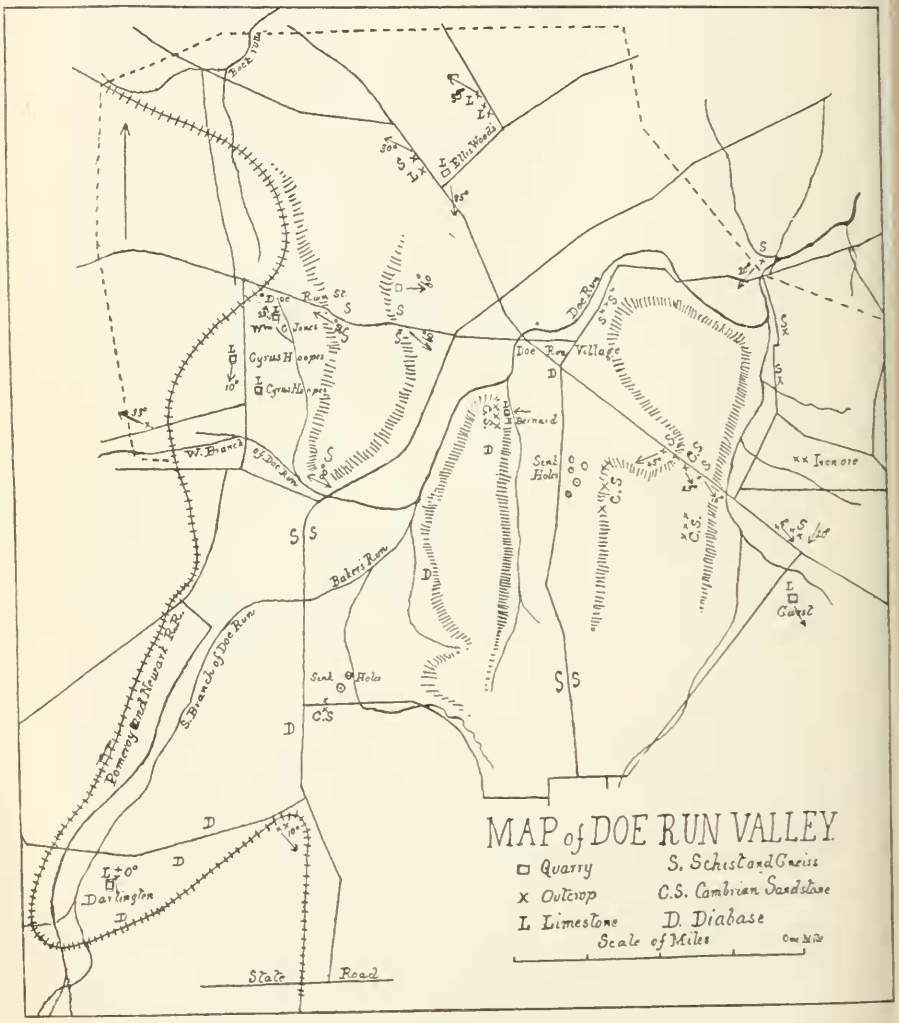
The only quarry in this location would be the large one in the bend of the Pomeroy & Newark Railroad, formerly Edwin Chandler's, now Walter Darlington's, near the source of the south branch of Doe run, but it seems impossible to consider this as being in a synclinal continuation of the former line for two hills, probably 150 feet in height, of sandstone and gneiss, intervene. Geographically it is nearly on the line of the quarries mentioned, but it seems to belong to the range of quarries north of it (William C. Jones, Isaac Hoopes) of the Doe run valley, presently to be mentioned.

IV. The Doe Run Valley.

The fourth or Doe run limestone seems geographically to be simply a continuation of the third, but I have deemed it best to consider it separately because in the subdivision I have made I have intended to include in each series those outcrops only which appear to be not only of one horizon, but also, in all probability, continuous underground when not visible at the surface, or at least not distinctly cut off. The accompanying is a sketch map of this valley.

Going northwestward along the Doe run road from the Guest quarry, as already stated, we cross southeast dipping mica schists, then southeast dipping Cambrian sandstone, then northwest dipping mica schist, and then no exposures, but a descent toward Doe run. To the north are high hills of gneiss and mica schist, through which Doe run and Buck run flow northeastward to the Brandywine. In front is Doe run valley, stretching in a general southwest direction. The floor of the valley is low and flat. It appears to be bounded on all sides by mica schists and gneisses, which also make prominent hills which subdivide it in part. Including these hills it is about a mile and a half from east to west

[81] *First Geol. Survey of Pa.*, I, p. 230. Quoted C^4, p. 72.


MAP of DOE RUN VALLEY.
□ Quarry
S. Schist and Gneiss
x Outcrop
C.S. Cambrian Sandstone
L Limestone
D. Diabase
Scale of Miles
Doe Run
Doe Run Village
Sink Hole
Baker's Run
S. Branch of Doe Run
Pomeroy and Newark R.R.
Darlington
State Road
Cyrus Hoopes
Wm. C. Jones
W. Branch of Doe Run
Bernard
Iron ore
Cabal

and about two and a half from north to south. Its southerly and westerly border is followed by the Pomeroy & Newark Railroad, which, going north, crosses the divide between White Clay creek and the Brandywine near Pusey Station, at about 470 feet above tide. A half-mile beyond, its direction changes abruptly from north to about west by south around the base of a high hill of hard schistose hornblende rock, dipping about 10° S. E. After keeping the west by south course for nearly a mile it crosses the headwaters of the south branch of Doe run, and then turns north by east along the high hill of mica schist bounding the valley on the west to Doe Run Station, about 374 feet above tide.[52]

In the valley are two prominent hills, both trending nearly north and south, in echelon, the westerly projecting from the northern highland, the easterly from the southern, from which, however, it is cut off by a branch of Doe run. On both sides of the westerly hill and on the east side of the easterly are limestone outcrops. The easterly hill, as shown by loose masses only, which, however, are in great abundance, is of hornblende schist and gneiss, but on its eastern flank near its northern end is an old limestone quarry (Enos Bernard's), in which the strike is very nearly north and south and the dip west, but whether 30° or 80° could not be decided, as the quarry has long been abandoned and but one mass of rock was well exposed. Within 150 feet west of the limestone Cambrian sandstone outcrops in abundance, but it is not exposed sufficiently to measure. The summit of this hill commands an excellent view of most of the valley. Across this hill the Downingtown diabase dyke strikes nearly southwest.

Looking southeast toward the Guest quarry, a mile and a quarter distant, there is a marked depression in the hills.

East of this hill is a road leading south to Chatham and north to Doe Run village. Just east of this road are five sink holes on land of Pusey Buffington and George Elvin, east-southeast of which is a hill about sixty feet in height, covered with sandstone fragments.

It seems not improbable that we have here a north and south

[52] These are from table 3, Levels above Tide, *Second Geol. Survey of Pa., N.* This table, however, gives Avondale 281.6, while table 141 gives it as 227. The geater elevation is probably most nearly correct as by table 141 Chadds Ford Junction is given as 129, but by table 41, 175. My own observation by barometer from West Chester as datum gave 170.

synclinal basin of the limestone and sandstone underlaid by mica schist, then an anticlinal of the schist, the limestone eroded, but appearing at the Guest quarry overlying the southeast dipping sandstone.

West of this hill, through low and flat ground, flows the main Doe run, beyond which is the westerly hill of hard and heavily bedded garnetiferous schists and gneisses, with limestone on both flanks, no sandstone being visible. This hill is fully a quarter of a mile wide and probably 150 feet above the valley. At its southern termination, near which unite the north, west and south branches of Doe run, the strike is N. 25° E., the dip nearly 90° The rock is hard, heavy-bedded gneiss. The road from Doe run to Gum Tree crosses the hill about a half-mile to the north, the strike of the gneiss being N. 40° E., the dip probably about 60° S. E., or under the limestone, which has been quarried about 500 feet north of this road (I. H. Thompson's quarry, formerly McNeal's). The limestone dips nearly east, 50° to 70°, and is more highly crystalline than at any other of the Doe run quarries. On the west slope of the hill a hard micaceous gneiss dips N. 60° W. 30°, about 700 feet northwest of Jones' limestone quarry. This hill, therefore, appears to be an anticlinal underlying the limestone, but exposing no sandstone. On the same flank of the hill as Thompson's, but a half-mile north, is the quarry of Ellis Woods,[83] where the limestone dips S. 80° E. 85°, bounded westward by the same garnetiferous schist, dipping N. 60° W. ± 35°, which appears also in fragments on all sides. The limestone is exposed on a northwest and southeast road, .25 mile northwest of Woods', dipping N. 65° W. 35°.

Crossing this anticlinal ridge westward, we descend into the western and most uninterrupted branch of the valley, drained in its northern part by a branch of Buck run and by the north branch of Doe run, and in its southern by the south branch. The northwesternmost quarry is that of William C. Jones, .1 mile south of the Doe Run-Gum Tree road. The limestone is much plicated and rolled with mica schist interbedded at the northern end. Dip at the northeast part, S. 30° E. 35°; north end, ± S. 20°; south side, S. 10° E. 20°. About a quarter of a mile south of Jones are quarries of Cyrus Hoopes, in plicated limestone like that of

[83] Hayes' quarry, C⁴, p. 70, but not Hayes' quarry, p. 309.

Jones' quarry, dipping S. 10° W. 10°. A little west of south of these, 1.5 miles, the intervening space occupied first by the westerly affluents of Doe run and then by the southerly branch, and almost at the head of the latter, is a very large quarry on the farm of Walter Darlington, formerly Edwin Chandler, and being almost certainly that mentioned by Rogers as Baker's quarry.[84] Here the limestone is nearly horizontal, with a quartzose mica schist overlying it, in some places twelve to fifteen feet thick; some pieces of the schist resemble somewhat the schists adjacent to the Cambrian sandstone, but most of it does not; its dip is likewise nearly 0°. This schist is well exposed in the cut of the railroad immediately southeast, where it does not at all resemble that close to the sandstone. East of it is a narrow outcrop of coarser mica schist, then the diabase of the Downingtown dyke.

There seems no great difficulty in regarding these westerly outcrops as the westerly leg of an anticlinal overlying the mica schist, and this would bring them into accord with the easterly outcrops. There are, however, two objections:

1. The sandstone is in great quantity at the easterly outcrops and is not found in the western.

2. The observed dips in the mica schist are steep, those in the limestone gentle.

On the map in C^4 the limestone is made continuous from Guest's to and including all the Doe run quarries, and to and including Logan's quarry west of Unionville. Fully three-fourths of this area show the underlying rock to be gneiss, schists or sandstone; the schists and gneisses forming high hills with abundant exposures, and there seems no reason to suppose that limestone underlies more than a fraction of the remaining one-fourth.

West of the Doe run valley there are no outcrops of limestone, and indeed, except within a mile or two, very few of any kind, and those of mica schist and gneiss; but in the southwest part of Highland township, on the limestone road, are two outcrops of limonite iron ore, in former years extensively mined. They are respectively .3 and .9 of a mile nearly south of the Fairview public school. About half a mile south-southeast of the southerly iron ore outcrop, on the farm of John H. Esbenshade, about a mile nearly east of Cochranville on the road to Gum Tree, is a sink

[84] *First Geol. Survey of Pa.*, I, 230. Quoted C^4, p. 72.

hole about 50 x 100 feet, and four or five feet deep in the centre. It seems not improbable that limestone underlies the schists in this vicinity.

V. Huntingdon Valley.

The fifth, the limestone of Huntingdon Valley, is the most concealed and probably the most limited in extent, but one of the most interesting geologically, for as shown by Mr. Hall[85] it is a very strong argument in favor of the paleozoic age of the Philadelphia schists and gneisses.

Huntingdon Valley is a straight narrow valley on the southeast side of the ancient gneiss of Buck Ridge. It is crossed by the Pennypack creek and drained by Paul's brook flowing east, and Huntingdon creek west, into the Pennypack. The valley proper extends in a straight line N. 70° E. for about four miles, but it may be traced further east less distinctly. East of the Pennypack creek the Cambrian sandstone intervenes between the limestone and the ancient gneiss, increasing in prominence eastwardly. West of the Pennypack, while there are indications of it in the same relation, they are not beyond doubt. The limestone itself is very obscure. It has been reported in wells and in pits dug for iron ore and by Mr. Hall[86] in the bed of Paul's brook, but the only place I have seen it is in the cellar of an old mill, now a wagon-house on the property of Mr. Penrose Hallowell, who informed me that many years ago there was a quarry in the limestone west of the wagonhouse. He pointed out a quarry of sandstone about 500 feet northwest from the limestone, not wrought for years. The rock in this quarry resembles the Cambrian sandstone, but it is coarser, more feldspathic, and not as well defined as at Waverly Heights, but in walls of the vicinity were slabs of the typical sandstone said to have come from this quarry. The sandstone apparently dips southeast, steeply, the limestone 60° southeast, and the spangled mica schist, well exposed 1000 feet southeast, S. 30° E. 60°, followed by the wood-like garnetiferous schist, nearly vertical.

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[85] C[6], p. 62.
[86] C[6], p. 67.

VI. The Limestone of Pocopsin Township, of Logan's Quarry and of Elisha Bailey's Quarry.

The first of these outcrops, perhaps, should not be grouped with the last two, the only ground for the grouping being their geographical position. Indeed, the first is in geological position nearer that of Huntingdon Valley, lying as it does about half a mile south of the ancient gneiss near the extreme western outcrop of the latter. It is in a small valley about .3 mile south of the State road, and about the same distance west of the road leading south from Pocopsin Inn to the Red Lion. It has not been wrought for nearly fifty years and now shows nothing but a hollow filled with water from a large spring. There is, however, besides tradition, a quantity of limestone fragments, and a little to the northeast a large sink hole. The limestone is granular and crystalline. It was wrought by James Gawthorp, and is now on the farm of L. M. Larkin. It appears to be surrounded by the schists, but no good exposures were seen. About 500 feet north of it is an outcrop of talc schist.

Four miles nearly due west of this quarry and 1.75 miles N. 70° W. of Unionville is the quarry of Eli Logan. This is still in operation. The dip, omitting one remarkable fold or roll, is quite regular, S. 35° to 50° E. 30° to 50°. On the Doe run road, immediately south of the quarry, garnetiferous mica schists dip S. 40° to 50° E. 40° to 50°. About .1 mile west of the quarry, mica schists dip S. 55° E. 70°, and about 300 feet further west Cambrian sandstone S. 75° E. 30°; this is close to the township line between East and West Marlborough. A little west of the line a road goes south to Upland (Marlborough Inn). On this road the sandstone is well exposed in two outcrops about 150 feet apart, with mica schists above, between and below the sandstone, all dipping about S. 40° E. 30°.

A remarkable feature of Logan's quarry, unique in the limestone quarries of this region, is the occurrence of a massive rock chiefly of plagioclase feldspar with some quartz, exceedingly tough and hard, containing much tourmaline. This has much the aspect of a sheet of igneous rock. It was observed by Rogers, who supposed it to overlie the limestone and to be possibly "a highly altered form of the upper primal slates." It seems to have

escaped the notice of the Second Survey. Quarrying, since the date of Rogers' notes, has shown clearly that it is a sheet or vein, apparently parallel with the dip of the limestone.

S. 50° W., 1.1 miles from Logan's quarry, is that of Eli S. Bailey, a half mile or less west of Upland.

This quarry, when in active operation thirty or forty years ago, was a famous locality for tremolite, which was found in larger quantity and in better specimens than elsewhere in the State, but almost nothing is showing now. The dip is probably southeast. The strike of the sandstone west and southwest of Logan's would bring it west and northwest of this quarry. It is not exposed nearer than the road north to Upland, but southeast dipping mica schists with considerable quartzite appear to the westward, on the State road.

VII. The Street Road Limestone.

The seventh group comprises a series of outcrops (on nearly all of which quarries have been opened) extending in a line about S. 70° W., somewhat curved to the north at the eastern end, and having a total length of thirteen miles. The easternmost exposure is about a quarter of a mile nearly due north of the south corner of Thornbury township, Chester county. It is in very sandy limestone, dipping S. 40° E. 50°. No other fast rock is exposed, but schist fragments are abundant, especially to the southeast. About .25 mile south a schist dips S. 30° E. 30°. A half-mile nearly east and about the same distance southeast typical Cambrian sandstone outcrops abundantly, dipping at the former N. 35° W. 80°, and a little further east S. ± 40° E. 20°, with schists above and below, dipping from 0° to 60° S. E.

The second outcrop is in Birmingham township, Chester county, about a mile and a quarter S. 35° W. of the first, on a small stream which empties into the Brandywine just above Brinton's Bridge. Evidently much rock has been removed, but the quarry is filled with water and mud. Southwest of it a trench was dug for drainage, showing a hard quartz schist, with the unusual dip of N. 60° E. 20° under the limestone. I could see no reason to doubt this dip.

The third, about .75 mile S. 70° W. from the second, is on the right bank of the Brandywine at Brinton's Bridge, about a mile

above Chadd's Ford, at Harvey's quarry. Here the limestone and adjacent rocks are well exposed. The latter are schists and gneisses, dipping S. 10° to 40° E. 25° to 70°. The limestone dips about S. 20° E. 45° under a hard quartzose mica schist, with quartz in serpentine forms, like those seen in the Manayunk schists. The schist as well as the limestone is plicated, one stratum making two 90° bends within a few inches. Under the limestone is a similar schist, less quartzose and finer grained, dipping S. 25° E. 25°.

It is very rare in this region to find a section as good as that afforded by the Brandywine. It is unfortunate that it does not show the structure more clearly. Prof. Lesley examined it and thought the limestone a tongued anticlinal.[87] While this may be the fact, I incline to the opinion that it is interbedded in the gneiss. The limestone of this quarry contains chondrodite, the only occurrence of this mineral in the region so far as I am aware. Dr. Frazer classed this limestone and that of Honeybrook township as Huronian or perhaps Laurentian.[88]

It is not certain whether these outcrops belong strictly to the Street road line about to be described, or to those in the valley to the south followed by the Baltimore Central Railroad, or one or more to each, or whether they constitute an isolated line. When we possess a good topographical map of the region it may be possible to determine.

About 1.25 miles north of Harvey's quarry the Brandywine is crossed by the Street road, which occupies an almost continuous nearly straight depression about S. 60° W. from a mile northeast of the southeast corner of Westtown township nearly ten miles to the Red Lion, in East Marlborough. It then bears about S. 80° W. to a point beyond White Clay creek and then about southwest through Oxford. In its vicinity is the line of quarries well described by Rogers under the title "Street Road Limestone Line."[89]

[87] *Proc. A. P. S.*, Vol. VIII, p. 282; also C^4, p. 239, where a drawing is given.

[88] "Calcaire Huronien. Il parait y avoir des examples isolés de calcaires intercalés dans les gneiss et les mica-schistes, un de ces examples se recontre dans le township de Honey Brook comté de Chester, et un autre se trouve sur la Brandywine a une courte distance de Chad's Ford. Dans ce dernier cas il est possible en réalité que le gîte de calcaire appartienne au Laurentian, dont une des bandes étroites passe ici dans l'aire du Huronien." *Memoir sur la géologie de la partie sud-est de la Pennsylvanie.* Lille, 1882.

[89] *First Geol. Survey of Pa.*, I, p. 226. Quoted C^4, p. 74.

For nearly its whole extent, east of Pocopsin creek, the Street road passes through mica schists, but after passing the creek and Parkerville the schists become very sandy, and near the Red Lion there is abundance of the typical sandstone with mica schists apparently on both sides of it, the dips being to the southeast and moderate. An exposure on the Street road near the schoolhouse .2 mile west of Red Lion, quite satisfactory, gave sandstone S. 25° to 27° E. 15° to 50°, with mica schist underlying within twenty feet S. 20° E. 25°. From this point a narrow straight valley trends nearly southwest. A mile and a quarter west of Red Lion, and .1 mile south of the Street road, is a quarry on the land of Barclay Cope, formerly Reynolds' quarry, then on the farm of Jacob Way.[90] The quarry is now full of water, no rock being visible. .75 miles west of this is Taggart's cross-roads, Willowdale P. O.; .75 mile west of this, on the farm of William Scarlett, formerly John Baily's, were, as I am informed, several sink holes, now filled up and farmed over. In the Street road, just north of this, the sandstone dips S. 5° E. 15° to 20° very clearly. Close west of the road which bounds this farm on the west are the quarries of Joseph H. Taylor, followed S. 50° W. from it by quarries of Henry Pusey, one north, the other south of an east-and-west road, at distances respectively of .3 and .6 mile from Taylor's. These quarries are in operation.

At Taylor's there are two quarries. The eastern, recently abandoned, shows clearly a mica schist containing tourmaline, dipping S. 30° E. 30° immediately southeast of the limestone. The westerly quarry is very close to the former and shows a highly crystalline limestone full of cavities, some water-worn, others not, with occasional quartz crystals in the cavities. From the upper portion the cementing material of the crystalline grains has been removed, leaving a lime sand which is utilized. The dip is southeast, probably less than 10°; overlying is the mica schist, much plicated, with a stratum about eighteen inches wide of the typical sandstone, with its rhomboidal jointings, micaceous partings, and stretched tourmalines; apparently the same rock that is dipping toward the limestone, about a half-mile to the northwest.

Within 500 feet southeast of the Taylor quarries is a mica schist, dipping S. 50° E. 50°, but including a sharply folded mass of the schist, and a convoluted mass of hard biotite gneiss.

[90] C⁴, p. 319.

Three-tenths of a mile S. 50° W. from the Taylor quarries is an old and large quarry on the farm of Henry Pusey[91] still wrought. On its southeast side the limestone dips S. 25° E. 50° under mica schists, in the northeast corner N. 25° W. 15°. Near the northwest corner sandy mica schist containing tourmaline appears next to the limestone for about twenty feet, and then a hard quartzose stratum of which very little is exposed, N. 35° W 70°.

Three-tenths of a mile S. 50° W. is the other Pusey quarry. Here the walls are not visible, nor the southeast part of the limestone, but on the northwest side the dip is N. 30° W. 10° to 15°. A peculiarity in this quarry is that the rock is partly blue and partly pure white, both very compact, but the change from one to the other occurs, not in what appear at first sight to be the lines of stratification, but at the joint planes nearly at right angles, which would seem therefore to indicate bedding planes.

Regarding the Taylor quarry and the northerly Pusey quarry, close together as they are, the presence of the sandstone in the former and its apparent total absence in the latter is remarkable. The exposure in the Pusey quarry is unusually good, especially the northwesterly wall, while in the Taylor quarries the southeasterly is best shown. If the dips at Pusey's are trustworthy we have the summit of an anticlinal, but the curves in the adjacent mica schist suggest caution. Dr. Frazer gives the dip (probably about 1879) as N. 30° W. 60° on the south face,[92] while our observations on the north side agree within 5°.

About half a mile west is the West Marlborough township line, and about .1 mile west of it a quarry of considerable size on the farm of Chalkley Bartram, formerly Eli Thompson, showing now nothing of interest. The next farm is that of Edward S. Marshall, on which there was a considerable quarry. Here sandstone fragments are abundant. The westerly boundary of this farm is the road leading south from Marlborough Inn (Upland) to Toughkenamon, being also at this point the west line of the tongue of West Marlborough, which projects southward. About a mile north of the limestone here, the sandstone is very well shown in large quantity, being the most extensive outcrop south of the North

[91] C^4, p. 312.
[92] C^4, p. 312.

Valley Hill. Its best exposure is on the road from London Grove Post-office to Chatham, at distances of .25 and .5 mile southeast of London Grove, the former a quarry in the typical rock, overlaid by sandy mica schist, both dipping S. 35° E. 30°, the latter exposures on the road showing the sandstone underlaid by mica schist, S. 25° E. 30° to 60°.

On the west side of the road from Upland to Toughkenamon, about .2 mile north of the north line of New Garden township, is a limestone quarry on the farm of Joseph Sharpless, formerly Ephraim Wilson, and another a little further west on that of Benjamin Swayne. The latter shows a dip of S. 35° E. 15° to 40°.

About a mile west-southwest of Swayne's is a quarry on the farm of Francis W. Hicks, formerly Elias Hicks, and a mile further in the same direction a very extensive one on the farm of Aaron Baker, known as Baker's, subsequently as the Acme quarry, and more recently wrought by the Avondale Marble Company. Originally this quarry was wrought for lime for building and agricultural purposes, but the decline of this industry impelled the owners to put down diamond drill holes. The cores obtained showed a good quality of marble. A large plant was erected and now for some years excellent building marble has been obtained in large blocks. The inferior grades are readily split, with little waste, into rectangular blocks, which find a market. The marble at the north end of the present excavation is about seventy feet below the surface, and it dips nearly S. about 20°. Overlying it is a mica schist of great compactness which was quarried out in large blocks and is used for retaining walls, foundations, etc.

The limestone of this quarry shows plications, but there is evidently a gentle southerly dip throughout, except near the south end where the limestone dips N. 25° W. 25° and abuts against mica schist, dipping S. 40° E. 45°, the contact (a thrust fault ?) being well shown in the railroad cut, nearly under the office.

Near the middle of the west side of the quarry is a stratum of limestone containing much tremolite, phlogopite and quartz, minutely disseminated, forming a very hard rock, sold as "granite," and apparently in demand.

A short distance south of the marble quarry, on the Jacobs farm, close to Baker Station, schistose gneiss, some of it with feldspar porphyritically enclosed, dips S. 35° to 40° E. 50° to 55°.

A little over a mile, a little south of west of the Acme quarry, is one of large size, but abandoned for years. This is the Levis Bernard quarry, with a dip of S. 62° E. 20° in the most regular portion, but the limestone is much plicated. This is the most western quarry in this line and is that mentioned by Rogers as the most westerly quarry.[93]

South of the Street road line at its westerly end, that is south of the Benjamin Swayne, Elias Hicks, Avondale Marble and L. Bernard quarries, there are several outcrops of limestone which will be discussed after the consideration of the next belt to the south.

VIII. The Kennett Limestone.

At about two miles south of the Street road line there is, west of the Brandywine but not far east of it, a valley even better defined than that of the Street road. This has been taken advantage of by the Baltimore Central Railroad, which, descending rapidly from Brandywine Summit to the Brandywine[94] (from 273 above tide to 129 above tide in three miles), crosses the watersheds between that stream and the branches of Red Clay and the east branch of White Clay creek, with a rise of but 183 feet, while the hills to the north and south are from 50 feet to probably 175 feet higher. At intervals in the bottom of this valley outcrops of limestone appear. The easternmost exposure is at Mendenhall's quarry, in Pennsbury township, about 1.2 miles west of the Brandywine. At the quarry almost nothing is now visible, but one apparently clear dip in the limestone was S. 60° E. 20° About .2 mile east of this, hence over it, was a coarse mica schist with much mica in distinct cleavages, with pegmatite and porphyritic feldspar and quartz, dipping S. 25° E. 20°. Westward there are no exposures near.

About two miles from the Brandywine is Fairville Station. A half-mile north-northwest of it is a quarry in hard schistose gneiss, dipping nearly S. ± 40°, and about the same distance, west by south, in a cut of the railroad, S. 20° to 40° E. 60° to 80°, while to the south of the railroad are large quarries of feldspar in a coarse pegmatite.

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[93] *First Geol. Survey of Pa.*, I, p. 227. Quoted C^4, p. 75.

[94] These are from table 141, "Levels above Tide," N., p. 158, but by my observations by barometer are about 50′ too low.

About three miles west of the Mendenhall quarry, and about 1.25 miles nearly east of Kennett Square, is the Sharpless quarry. The greater part of this quarry, which has yielded a large amount of limestone, is under water, so that a measurement could be had at one point only, giving E. 10°; .3 mile northwest, a sandy feldspathic mica schist dips S. 25° E. 25°, while a half-mile northeast there is a decomposed very sandy schist, with feldspathic and quartzite layers and rhombic fracture very closely resembling the typical Cambrian sandstone, dipping S. 10° W. 30° or toward the limestone. From this vicinity westward the same sandstone appears to bound the valley on the north wherever the rock is well exposed as far as West Grove,[95] except for a short distance near Avondale where a gneissoid mica schist, containing garnets and tourmaline, forms the north hill, known in a large part of its course as the Toughkenamon hill. This rock seems to underlie the sandy schist and to form the greater part of this hill. It is fire-resisting and has been much used for lining limekilns and is called, locally, firestone.

The southerly hill, for about four miles at least, contains a very hard compact hornblende gneiss with nearly vertical dips, not improbably an altered intrusive rock. Near it are indications of mica schist, but no clear outcrops, the hornblende rock being the chief rock visible, but, except southeast of Kennett Square, it appears in large loose masses only.

One mile west of Kennett Square Station, and just east of the western line of New London township, close to the right bank of the west branch of Red Clay creek, is Joseph A. McFarlan's quarry. This is of large size and is wrought at present in a small way for building stone. A spring of considerable volume rises in the quarry. The rock is a pale blue and white limestone, very compact. Two dips about 600 feet apart were S. 20°. North of the quarry are no exposures, to the south ± 700 feet there is a hill of some fifty feet in height of mica schist and schistose gneiss, striking north to N. 30° E. and dipping about 70° W. to N. 60° W., or toward the limestone.

Half a mile a little north of west of McFarlan's quarry was one on the west branch of Red Clay creek, north of the railroad.

[95] That is, if the valley in which is West Grove be the continuation of that under consideration. This will be further discussed.

It is wholly overgrown. A quarter of a mile nearly west of this is a quarry on the State road, showing a jointed very sandy mica schist, dipping S. 33° E. 35°. This is .2 mile northeast of Toughkenamon Station. On the Newark road, about .2 mile north of Toughkenamon, similar schists are exposed near the schoolhouse, dipping nearly 0° at the north part of the exposure then steep northerly, while toward the south they dip ± 70° ± S. 45° E.

About .6 mile, a little south of west of Toughkenamon, was the Roberts' limestone quarry, now of Mr. Sharpless. The dip in this is S. 33° E. 35°.

Three-quarters of a mile west of this quarry is Avondale, and the apparent ending topographically of the valley which we have followed from the Brandywine. Here the high northern hill is cut by White Clay creek, of which the two northerly branches, one flowing nearly south, the other southeast, unite in this gap.

Nearly in line with the quarries mentioned and about two hundred yards south-southwest of Avondale Station is a quarry, now full of water, but with the limestone walls still in evidence. This quarry is the most interesting of the region if, as seems probable, it is that in which Dr. Frazer found, adjoining the limestone, the sandstone containing *Scolithus*.[96]

This is the westernmost quarry certainly of this series. A little more than a mile to the north is the Street road line of quarries; hence the two are closer than at the Brandywine. Between the two and to the westward are a number of limestone outcrops briefly referred to before, but worthy of detailed description. They, and the western part of the Street road line and the Watson & Jones' quarry, are within a parallelogram less than two miles from north to south and three miles from east to west, with Avondale in the southeast and West Grove in the southwest corner. From Avondale radiate three prominent hills of mica schist and gneiss:

1. Eastward the Toughkenamon hill, practically continuous to the Brandywine.

[96] C^4, p. 333 and p. 324. The quarry is on the land of Watson & Jones, but is not far from the John Williamson property, and is on the road leading south. At present no sandstone is visible. The limestone dips nearly west about 30°. Northeast of it and within 30′ is a hard gneiss dipping with and under the limestone. Dr. Frazer's dips for the sandstone were "W. 20° N., W. 10° N. to W. 10° S. with a dip of about 28°," and for the limestone "W. 10° N. 40°."

2. Westward a hill of mica schist, gneiss and pegmatite convex to the north, bounded northward by the westerly branch of the east branch of White Clay creek.

3. Northwestward the hill on which much of Avondale is built, and along which the Gap and Newport pike runs.

The eastern line of the parallelogram is nearly the eastern line of New London township, and is occupied by the rather flat nearly north-and-south valley of the northerly branch of the east branch of White Clay creek. In this valley, and near the creek, are outcrops seemingly connecting the Street road and Kennett series. To the north is the Benjamin Swayne quarry of the Street road series, S. 35° E. 15° to 40°, and half a mile south of it, on the bank of the creek, an outcrop S. 50° E. 30°, the former just north of the northwest corner of New Garden township. A quarter of a mile further south is the quarry of Joseph Quarll, in which the limestone dips nearly S. ± 15° on the south side, nearly 0° on the north side, and N. ± 10° on the west side; no adjacent rock is visible. A half-mile south-southeast are three quarries close together, the northerly one wrought chiefly for a lime sand, or highly crystalline limestone or marble altered by partial decomposition, by which the cohesion of the grains has been destroyed. This sand is used largely by florists for propagating purposes, and is said to be superior for that use. Some of the limestone under the sand is highly crystalline and pure white, a true marble. It is wrought by Michael Murphy. The dip is about S. 20° E. 20° About 200 feet south of this is Watson's quarry, a very impure limestone in large solid blocks, used, I was informed, for building purposes, and not for lime. The only exposures are on the south side, due S. 40° and S. 20° E. 25°, S. 65° E. 10°. As before, high hills, apparently wholly of mica schist and gneiss, are to the east and west. Seven-tenths mile south-southeast of this, mica schist and gneiss dipping S. 30° E. 15° to 50° intervening, we have the limestone of the quarry on property of Watson & Jones, seemingly of the Kennett series, already mentioned. As already stated, all these six outcrops are in a line almost due north and south, and within the space of a little over one mile.

To the westward and near the north line of our parallelogram are the quarries, already described, of the Avondale Marble Co.

and of Reuben Barnard. South of the latter is a high hill of garnetiferous mica schist, south of which are two quarries, both known as Storey's, one on each side of the road leading north from West Grove to Barnard's quarry. They lie in a small east-and-west valley on an affluent of the west branch of the East Branch of White Clay creek. The eastern is quite small; it shows a dip of N. 45° W. 65°. The western, though larger, is but a small quarry compared with most of those of the region; it shows, however, a distinct anticlinal structure, dipping on the southeast side S. 30° E. 30°, at the west end about the same, and on the northwest side N. 60° W. 65° within twenty feet of the moderate southeast dip, the intervening space being concealed by talus.

On the northerly side a small spring issues from the limestone, the water bearing with it at the time of my visits a continuous stream of lime sand.

North of the Storey quarries and separating them from the Barnard quarry, the westernmost of the Street road line, is the hill of mica schist above mentioned, somewhat garnetiferous, on the north slope of which, near the foot, is an insignificant outcrop of the sandstone, loose fragments only, but apparently in place. The mica schist is decomposed at the surface, and I was unable to find any satisfactory dips. Dr. Frazer, however, writes of this hill as one "in which the chloritic mica schists lie almost flat, or with very small angles of dip. These schists seem to be similar to those in and below the South Valley Hill. . . . . Without some change of structure which surface indications offer no right to suppose, there is here a limestone synclinal holding a hill of chloritic mica schists.

"On the south side of the West Grove quarry[97] the dip is S. 30° E. 30°, showing that it has been opened on an anticlinal which is, however, of very insignificant breadth as the sand rock (Potsdam) curves in a few hundred yards below it with a dip of W. 10° N., raising the calcareous beds beyond our present surface."[98]

It is much to be regretted that the outcrops here are so few and poor. Dr. Frazer's interpretation may be correct, but the small outcrop of the sandstone on the Chatham road southeast of Lewis Barnard's quarry and the gentle southeast dipping outcrops to the

[97] Probably the westerly Storey quarry.
[98] C⁴, p. 332.

southeast of the Storey quarry are difficulties. The decomposing garnetiferous mica schists of the hill between Barnard's and Storey's do not appear to me to resemble in the slightest degree the hydromica schists of the South Valley Hill, but more to resemble the mica schists lying to the southward of the hydromica, and clearly overlying the limestone of the Poorhouse quarry and of the quarries on the right bank of the East Branch of White Clay creek. The westerly Storey quarry certainly exhibits an anticlinal structure, as Dr. Frazer observes, "of insignificant breadth." The dip of the sandstone W. 10° N. I did not observe. About .3 mile southeast of the quarry there is a quarry in the sandstone giving an excellent exposure and a dip of S. 50° E. 20°. A quarry in similar rock but harder .25 mile to the eastward dips S. 35° E. 30°. The sandstone forms a hill about a hundred feet in height between the Storey quarries and the very extensive quarries of the Avondale Lime and Stone Co., formerly Hughes quarries, on the right bank of the East Branch of White Clay creek, about a mile west-northwest of Avondale and about a mile east of the Storey quarries. Here the limestone has a varying but very gentle southerly dip, probably averaging S. 10° to 20°, and is overlaid by garnetiferous mica schists conformably. The rock is highly crystalline with interstratified beds of mica schist. It has been wrought to a depth of over one hundred feet.

Although the limestone of this quarry seems to have throughout a regular very gentle southerly dip, evidence of peculiar folding is seen, as shown in the annexed photograph taken by Mr. George Vaux, Jr., a view of a small part of the south wall of the quarry. Here, although the stratum has nearly horizontal surfaces on this section, there is a complete fold within the stratum which was about three feet in width.

In this quarry is a stratum which contains masses of quartz of lenticular form, as if flattened pebbles. These have a coating of damourite, and have sharply defined parallel partings, also coated with damourite. A variety of this quartz was uncovered in 1897, partially filling what had evidently been a crevice dipping southwardly about 45°. The aspect of the quartz was exactly as if it had been a viscid substance like asphalt, flowing over an edge down a slope, forming masses like flattened stalactites, joined at the top only. They were a foot and less in length, about a half-

inch thick at the thickest part, and from an inch to three or four inches wide, all tapering downwards. All had a thin coating of damourite except at the top.

FIG. 2.—Fold in Limestone Quarry, one mile W. N. W. of Avondale.

On both sides of the Hughes quarries are outcrops of coarse pegmatite, that to the eastward being in contact with the limestone striking nearly northeast and southwest; just north of it schists dip S. 40° E. 63°; that to the westward is less than .1 mile distant from the westernmost quarry, and strikes N. 30° E. The northerly hill, which the Gap and Newport pike ascends northwest from Avondale, is of garnetiferous mica schist, in part at least. Southwest of this on this line no sandstone has been observed, but the valley continues.

Prof. Rogers construed these limestones as forks of the Street road line, seeing it divide westward into "three subordinate nar-

rower valleys, all of them containing limestone more or less continuously, and all of them ending westward in the vicinity of West Grove Friends' Meeting-house."[99]

While this may be the structure, including in the northerly subordinate valley the marble quarry and Barnard's, in the middle Quarll's and Storey's, and in the southerly the Avondale Lime and Stone Co.'s, it cannot include the quarries south of Quarll's. Moreover, as we have north of the Street road line a wide and persistent outcrop of the Cambrian sandstone, we should find more of it to the south than the small outcrops south of Barnard's and southeast of the Storey quarries.

IX. The Limestone of Nevins' Quarries.

The southern portion of New Garden township, Chester county, is a triangle, bounded eastwardly by the curved portion of Mason and Dixon's line (twelve miles from New Castle as a centre). Here and to the westward, in London Britain township, we find the most southerly Chester county outcrops of limestone, ranging in a general east-northeast and west-southwest direction in Broad Valley drained by Broad run, an affluent of White Clay creek. There are four quarries in Pennsylvania and one in Delaware. The latter is Jackson's quarry, near Hockessin Station on the Delaware & Western Railroad, near extensive kaolin mines. It is a highly crystalline limestone, but now shows nothing of the adjacent rocks.[100]

East-northeast of this limestone, among the schists and gneisses of southwestern Delaware county, in Birmingham township, is a single outcrop of limestone mentioned by Mr. Hall,[101] though represented on his map as serpentine. It was known as Bullock's quarry and, as I am informed by Mr. T. E. Bullock, was wrought by his grandfather, Thomas H. Bullock, fifty or sixty years ago and burned into lime on the spot. Kaolin was afterwards mined close to it and the outcrop obliterated. It is one mile west-northwest of Elam, about two miles from the Brandywine and one and

[99] *First Geol. Survey*, I, p. 226. Quoted C⁴, p. 74.

[100] "The magnesian marble which outcrops . . . . at Nevin's runs into Delaware, and appears at the surface in the Jackson quarry at Hockessin. Here the rock forms a clearly defined anticlinal fold; . . . . the limestone is overlaid by the mica schists." F. D. Chester, *Proc. Acad. Nat. Sci.*, 1884, p. 248.

[101] C⁵, p. 47.

three-quarters from the Delaware line. It does not fall in line with any of the nearby outcrops, being south of the Kennett line and of the outcrops near Brinton's bridge. About two miles nearly west of Jackson's quarry, near Broad Run Station, is the quarry of David M. Brown, with a dip S. 60° E. 25°, with some gentle waves.

About a mile and a half west of the Brown quarry limestone outcrops in the road, and a little west of this, east of the East Branch of White Clay creek, an affluent of the Christiana, is the David Nevin's quarry, or Septimus Nevin's, showing a dip on the south and west sides quite regular S. 25° E. 25°, while on the northwest side the exposure was poor, but dip apparently nearly 0° to 10° S. E.

Of this quarry Prof. Rogers wrote as follows, these quarries then being in active operation: "D. Nevin's quarry, on the east side of the East Branch of White Clay creek. The strata dip at a gentle angle southeastward, and a low anticlinal undulation, or saddle, lifts the talcose slates underlying the limestone to the bed of the quarry. . . . . The limestone is overlaid by the ordinary very micaceous rock dipping on the south side of the quarry gently south, and there is a dyke of granite at the south margin."[102]

West-southwest of David Nevin's is one of Edward Sharpless, now showing no good exposures, and in the same direction about three-quarters of a mile from the former are two closely adjacent quarries of John Nevin; of these the easterly gives excellent exposures. On the northwest side the dip is N. 50° W. 25° with mica schist and gneiss overlying apparently conformably, on the southeast side S. 50° E. 10°, on the northwest side at the northeast end N. 60° W. 40°, becoming more gentle toward the middle to 0°, then débris conceals the following probably southeast dip.[103]

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[102] *Geol. Survey of Pa.*, Vol. I, p. 225.

[103] Of this quarry Prof. Rogers wrote: "An anticlinal axis runs through the quarry about N. 60° E. On the north side of this saddle the dip is about 45° under a micaceous gneissic-looking rock. The dip on the south side is to the south about 30°." Vol. I, p. 225.

Of one of the quarries, but which one is not clear, Dr. Frazer writes: "At Nevin's quarry the limestone dips W. 10° N. 10° to 20° in the middle portion of the quarry and steep at the extremities, which, compared with the southeasterly dip of the quarries in New Garden and just within the northeast border of London Britain (which latter is ± S. ± 20)" (probably the David Nevin's quarry—T. D. R.) "compel one to regard the structure here as an anticlinal of limestone though one of very gentle dips. . . . A

I was able to find no rock closely adjacent to the limestone on the southeast side; on the northwest the rock clearly is not the sandstone, but mica schist and gneiss. One dip on the Delaware & Western Railroad (or Wilmington & Landenberg Railroad), nearly a mile west of the Brown quarry and .2 mile northwest of limestone exposed near the Nevin's quarries, was S. 60° E. 30° to 60° in decomposing mica schists.

About three miles nearly south of the Nevin's quarries and near Peach's kaolin mines, in New Castle county, Del., is a series of large quarries, known as Eastburn's, on the easterly slope of a hill, two on the east and two on the west of the road to Newark, Del. Unlike the Chester county outcrops, these four quarries are nearly on the line of dip; two of them are quite extensive. The limestone is much plicated. Overlying the southeast quarry on the southeast side are fragments of mica schist and pegmatite. The north wall of this quarry is a mica schist dipping N. 65° W. 65°, but northwest of this and within 200 feet is the next quarry with limestone dipping S. 40° to 50° E. 20°, with no rock exposed except the limestone and schist fragments. No sandstone was observed, except in indistinct fragments, one of which contained rutile.

X. Outcrops in Northern Chester County.

In northwestern Chester county we have successive outcrops of the sandstone with adjacent beds of limestone, most of them very clear, but one obscure and with resemblance to those south of the valley. In the north is the great sandstone outcrop of the Welsh mountain, with the Lancaster Valley limestone northwest of it. Going southward the limestone does not appear south of the sandstone, but a very hard gneiss, like the ancient gneiss, with dykes of igneous rock. South of this is a valley with limestone near the southerly edge of Honeybrook township, followed by the prominent

mass of quartz sand rock and quartzite fragments underlies this limestone to the southeast coming in from the State of Delaware." C^4, p. 327.

Dr. Frazer does not explain how this is possible in view of the anticlinal structure and gentle southerly dips on the southerly side. On the map in C^4 an area of sandstone (Potsdam) is shown nearly surrounding these outcrops. Prof. Chester, however, states that in the northwest part of Delaware a coarse quartzose rock underlies highly crystalline magnesian marble which must be referred to Potsdam and Calciferous. F. D. Chester, *Proc. Acad. Nat. Sci.*, 1884, p. 239.

Baron ridge of the sandstone, extending unbroken from Lancaster county to a point east of the East Branch of the Brandywine in Wallace township. South of this, in the western part of West Caln township, is the easterly end of the limestone of the Pequea Valley. South of it is another prominent ridge of sandstone, probably connected with that of the Baron ridge close to the Lancaster border, but giving place to gneiss in the valley of Birch run. This ridge of sandstone, much smaller than that of the Baron ridge, reaches but apparently does not cross the West Branch of the Brandywine north of Wagontown, its easternmost outcrop being on the Brubaker farm just north of a steatite outcrop, an old Indian quarry. South of this is gneiss and then the sandstone of the North Valley Hill. The sandstone, as usual, forms high nearly straight ridges. Gneiss appears in the intermediate valleys. Possibly there is limestone in these valleys, for that in the valley in the south part of Honeybrook was exposed in one quarry only, and is now invisible.

There are outcrops of limestone in Chester county east of the Brandywine, but none of any magnitude. Thirty to fifty years ago when lime was in demand for farming purposes, it was the custom of farmers near limestone outcrops to have kilns of their own. Wood was abundant, and in winter labor also. By this means every outcrop was quarried, the hauling being one of the most serious items of expense. All this being changed the quarries have been abandoned, filled up and grown over and even forgotten by the present generation. While this is true of outcrops in many parts of Chester county, it is particularly true of those in the section now under consideration, the outcrops having been mostly in low ground and small in size. Nothing, therefore, can be added to Prof. Rogers' descriptions, made when most of the outcrops were wrought. He describes ten in Charlestown, East Pikeland, West Pikeland, East (West?) Vincent, South Coventry, Nantmeal, Warwick and Uwchlan townships.[104]

In discussing the relation of these rocks it may be useful, first, to sum up the facts that seem to be beyond question:

(1) The peculiar sandstone is below the limestone of the Chester Valley.

(2) Mica schists occur between the two.

[104] *Geol. Survey of Pa.*, I, p. 231. Quoted C^4, p. 82.

(3) All the limestone outcrops south of the Chester Valley are among schists and gneisses which appear to cover by far the greater part of the area, the dips being almost invariably to the southeast and not steep.

(4) Some of these schists are very sandy and not infrequently include strata of the peculiar sandstone.

(5) Nearly every line of limestone outcrops has adjacent to it outcrops of the sandstone, usually on the northwest side, with mica schists usually intervening.

(6) At no locality (except one in the Doe Run Valley) do we find, with satisfactory clearness, an orderly succession of rocks, making an undoubted synclinal or anticlinal.

(7) At several of the localities south of the Chester Valley mica schists, sometimes garnetiferous, overlie the limestone conformably and clearly.

There is no lithological evidence of the identity of the limestone of the different outcrops. The variation in this rock is so great that even in the same quarry the most diverse characters may be found. The opposite, however, is true of the sandstone. It has a very peculiar and well-marked character in its rhomboidal jointings, its micaceous partings, and its stretched and broken tourmalines. While it must be admitted that lithological evidence is of little weight in determining the age of a rock, yet when the lithological character is so well defined and when, in addition, the close association with the limestone is marked, together with the fact that the outcrops are not widely separated, the evidence of identity of age is not weak. But if the sandstone is of one age, it seems difficult to believe the limestone which seems to accompany it so closely is not of the same age as that which overlies the sandstone of the North Valley Hill, unless, indeed, there is one limestone just below and another just above the sandstone with mica schists intervening. Of this the only evidence is Taylor's quarry, and that is very meagre. The sequence of rocks at nearly all the localities would be satisfied by southeast dipping sandstone overlaid by schists and they by limestone and it by schists, and this longitudinally faulted, but as the succession is at least eight times repeated such explanation is not satisfactory. Equally does a succession of anticlinals and synclinals fail, for surely we could not

then have so uniform gentle southeast dips and we should have a more orderly succession.

A curious feature is the westerly ending of several of these lines in north-and-south limestone valleys—thus the Chester Valley in the valley of Big Beaver creek; the Cream Valley-Poorhouse-Embreeville-Guest line in the Doe Run Valley; the Street road and the Kennett lines in the valley of the East Branch of White Clay creek. Another feature is that in all these north-and-south valleys the dip of the limestone is much less steep than that of the other outcrops and of the adjacent schists. These taken alone would indicate flat synclinals of which the axes rise westwardly.

When, however, we attempt to fit any theory to the facts, we find constantly one or more stubborn ones which block the path.

Taking the second and third series, those of Chester Valley and of Cream Valley, the facts all agree perfectly with a synclinal structure, both legs of the sandstone and limestone appearing with the hydromica in the middle, the rock which is wholly sandstone on the north being only partially so on the south and largely mica schists, but with enough of the peculiar sandstone to identify it clearly. However, when we trace westward what appear to be the same strata we find the sandstone among similar schists to the northwest of the limestone instead of to the southeast.[105] Again, along and north of the Street road line the sandstone is very well shown for a distance of eight miles nearly continuously, with first schists and then schists and limestone overlying, but in Taylor's quarry in this series the sandstone appears interbedded in the schists overlying the limestone. It is true that it is but eighteen inches thick, and is visible in but one small quarry and is not shown in a much larger one only about .3 mile south-southwest.

If Dr. Frazer's conclusion is correct that the limestone of Barnard's and Storey's quarries are opposing legs of a synclinal, the hill of schists between overlying, then the hill to the south, whether it be regarded as the continuation of the Toughkenamon hill or as an independent ridge, must represent the London Grove sandstone. Dr. Frazer[106] gives a dip in the sandstone of W. 10° N. (N. 80° W.), which would be in accord, but, as above stated, there are quarries in this narrow hill giving excellent exposures

[105] Poorhouse quarry ; Guest quarry.
[106] C⁴, p. 332.

with gentle dips to the southeast, according with the dips of the limestone further southeast.

The Hydromica Schist.

For these schists I prefer to retain Prof. Dana's name, although not free from the objection that the mica is probably not more hydrous than that of those known as mica schists. The term talc-mica is certainly incorrect. In them I include only the soft micaceous schists such as are everywhere to be seen on the northerly slope of the South (Chester) Valley Hill.

This rock is composed of minute scales of mica, perhaps damourite, with quartz. With rare exceptions it is soft and, on the broader surfaces at least, unctuous to the touch. When almost free from quartz, it forms a rock so ductile that the blow of a hammer upon a mass will not break it, but simply indent it, or if not too thick make a hole. Strata of this variety occur of considerable thickness, but more commonly much quartz occurs with it, usually in lenticular masses, the quartz more or less cellular and rusty, the surface of the quartz coated with closely adherent mica. Rarely the quartz occurs in beds of one to three feet in thickness. It forms the whole of the hill from its beginning near Marble Hall, Montgomery county, to East Goshen township, Chester county, except the comparatively small space occupied by the Conshohocken trap dyke. As far west as Wayne the hill is very well defined on its southern slope, as it is throughout its whole extent (except at its extreme eastern end) on its northern. West of Wayne no distinct valley separates it from the mica schists which border it on the south and which here begin to widen out. North of Radnor Station it is less than a thousand feet north of the ancient gneiss, and at Wayne but little more, while twenty miles to the westward, between the two branches of the Brandywine, over two miles of mica schists, etc., intervene.[107] In occasional

[107] In the *Final Report* it is stated : "The South Valley Hill hydromica schist belt from the Delaware-Chester county line west to the Brandywine has a south border fairly defined by a straight range of serpentine outcrops and limestone quarries." As more fully shown elsewhere, a triangle of mica schist, with included gneiss, and carrying garnets, kyanite and staurolite, intervenes. On the Delaware-Chester county line (Devon) no rock is visible between the serpentine and the hydromica, but to the westward as well as to the eastward the schists and gneisses intervene, increasing in width westwardly to nearly three-quarters of a mile at the East Branch of

beds there is a highly quartzose variety containing little mica, but still enough to make it distinctly a schist.

These rocks are usually olive-green in color, weathering to yellow and red, and rarely to purple tints.

A curious error in regard to these rocks has been remarkably perpetuated. When Prof. Rogers wrote, they were known as talcose schists, the distinction between talc and damourite, etc., being hardly recognized, but when that distinction was made clear these rocks were shown to be not talcose at all, being destitute, or nearly so, of magnesia.[108] Notwithstanding this they are termed talc schists repeatedly in the volumes of the Second Geological Survey, and chloritic schists and chloritic mica schists by Dr. Frazer.[109]

The following analyses of true chlorite schists and of these hydromica schists by Dr. Genth are instructive:

1. Talcose chlorite slate, Prince's quarry, near Lafayette (Montgomery county, Pa.). C^6, 128.

2. Chlorite slate from the same. C^6, 130.

3. Chlorite mineral, Rose's quarry. C^6, 130.[110]

4. Hydromica schist from road between Gulf Mill and Hitner's marble quarry. C^6, 132.

5. Ferruginous hydromica schist between Gulf Mills and King of Prussia. C^6, 133.

6. "Hydromica slate 1222 feet from Bird-in-Hand tavern on road Gulf Mills to Bryn Mawr." C^6, 133. (This therefore is from in the Gulf.—T. D. R.)

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the Brandywine, where much of the rock is heavy-bedded and hard and very different from the hydromica schists.

[108] Dr. Frazer, *Am. Nat.*, Oct., 1883, p. 1021.

[109] C^4, p. 103; *Journal Franklin Inst.*, April, 1884, C^4, pp. 284, 292, 297, 304, etc.

[110] A serpentine quarry on the west bank of the Schuylkill just above Lafayette.—T. D. R.

	Chlorite Schist.			Hydromica Schist.		
	1	2	3	4	5	6
Loss by ignition, .	9.07	12.60	12.88	7.52	5.91	6.05
Silicic acid, . . .	41.80	32.78	39.39	43.81	43.10	39.35
Titanic acid, . .	.52			3.78	3.28	1.20
Phosphoric acid, .	trace			.13	trace	.49
Alumina, . . .	10.39	17.53	5.07	27.52	30.86	31.92
Ferrous oxide, . .	7.29	3.90	3.25	trace		9.
Ferric oxide, . .		1.31	4.69	7.30	7.28	2.19
Magnesia, . . .	26.71	31.56	34.34	1.77	1.80	3.08
Lime, ...	3.89		trace	.19		
Soda, ...	.27			.56	.66	1.98
Potash, ...	.06			8.81	6.87	5.26
Lithia, ...				trace		
Ni.O., ...						.06
	100.	99.68	99.62	101.39	99.76	100.58

My observations lead me to the conclusion that throughout nearly the whole of their course, from the Schuylkill on the east to far beyond the Octorara on the west, there is not the slightest difficulty in distinguishing the line between the hydromica and the mica schist on the south of it, except that often the margin is concealed by the decomposition of the rocks, as usual in this region. It is, however, quite as well defined as any of the margins except those of the ancient gneiss and the serpentines.

In the mica schists which are south of the hydromica, talc schists and probably chlorites do occur, as near Copeland Schoolhouse, East Bradford township, Chester county, near Mortonville, and on Buck and Doe run, near the Brandywine in East Fallowfield township, but they are rare and always easy to be distinguished

In the northeast the hydromica schist belt first appears in the Whitemarsh (otherwise Plymouth, otherwise Montgomery Valley, the northeasterly continuation of the Chester Valley) not far from Marble Hall. It continues to Conshohocken as a high hill, bounded on all sides, except the southwest, by limestone, which in its turn is bounded by Cambrian sandstone and it by the ancient gneiss. At Conshohocken the Schuylkill flows through it and it is well defined, extending from the Mattson's Ford road to the Gulf creek, bounded on both sides by limestone and intersected by the Conshohocken diabase dyke.

One of the prominent features of this belt is its remarkable

widening west of the Schuylkill. From its beginning to the Schuylkill it is about a thousand feet in breadth. It forms the hill on which Conshohocken is built. West of the river it forms a hill of about the same width and 300 feet to 400 feet high for a mile and a half, where it is cut by the Gulf creek to a level of about 150 feet. This creek, flowing eastwardly through the upper part of Cream Valley and near the southerly edge of the hydromica, here turns abruptly northward through a very steep-sided gap known as "The Gulf," and then turning abruptly eastward flows on, or very near, the northerly line of the hydromica into the Schuylkill. The illustration of this gap was taken by Dr. Charles Schäffer.

FIG. 3.—The Gulf.

A very little west of the line of this gap, two steep, nearly parallel hills of hydromica appear rising out of the limestone plain which bounds it on the north, and widen the belt at once to a mile and a half. It would be interesting to know whether the floor of the intermediate valleys is of limestone, but no rocks are visible in the valleys, and I have been unable to find trustworthy dips except

in the southernmost hill. The strike is evidently nearly coincident with the trend of the hills ± S. 60° W. In the Gulf, at the south entrance, near almost vertical limestone of Cream Valley, the dip is N. 30° W. 70°, soon becoming 90° and then S. 25° E. 80° near the north entrance and the limestone of the Chester Valley, making a synclinal if the rock is stratified and dips so steep are trustworthy. This was Mr. Hall's view, while Dr. Frazer thought it anticlinal. The limestone in front of the promontories dips S. 20° E. 70° to 90°, S. 30° E. 75°.[111]

About three miles west of the Schuylkill, the Radnor and King of Prussia road crosses (N. 25° W.) nearly on the dip line. The southerly of the two valleys ends a short distance east of this road, the northerly a short distance west of it, the hills becoming a tableland two miles broad with deep, precipitous gorges on its steep north slope, and more gentle ones on its more moderate south slope, but without a gap for nearly twenty miles. It is here 350 feet to 450 feet above tide.

From the road just mentioned for about a mile the schists still form a hill distinct on the south as well as on the north, but in the vicinity of Wayne the floor of Cream Valley—composed in great part of the mica schists, here very full of garnets, some of large size, with Cambrian sandstone and, probably (a mile east, *certainly*), limestone—rises to 370 feet, and the southerly portion of the hydromica schists is no longer a prominent hill though it still occupies the highest ground, attaining an elevation of over 500 feet above tide.

At Wayne exposures of the two series are close together, but the rocks are entirely distinct one from the other. The hard garnetiferous schist in Fenimore's quarry, north of St. David's Station, dips N. 34° W. 75°; the hydromica schist in the well of the water-works east of the Radnor Street road, distant from the quarry .3 mile N. 40° W., dips S. 25° to 30° E. ± 70°. Both

[111] The Schuylkill Valley Railroad cuts the Conshohocken hill east of the Schuylkill. The hill is apparently wholly of hydromica (except the diabase dyke), yet in this excavation, at the railroad level, immediately northwest of the dyke, was abundant limestone, nearly vertical, apparently underlying decomposed hydromica schist, also nearly vertical. Directly across the river the strike of the hydromica (N. 60° E.), of the limestone (N. 62° E.), and of the trap dyke (N. 65 E.) being approximately the same, and the distance about 1,000 feet, the dyke is separated from the limestone on each side by about 500 feet of hydromica.

these exposures are excellent. The two rocks may be seen between the above exposures within 500 feet of each other, and in the branches of Gulf creek, the mica schist with a rock much resembling the Cambrian sandstone striking N. 70° E., dip uncertain but steep; the hydromica with a dip 60° to 80° S. 30° E. with iron ore and sink-holes adjacent.

Just west of Wayne, the Pennsylvania Railroad crosses Cream Valley by an embankment, at the foot of which the garnetiferous mica schist may be seen, and enters a cut showing abundant fragments of a gneissic rock (probably the Altered Primal of Rogers), the diabase of the Conshohocken dyke, and the typical Cambrian sandstone. The latter was abundant when the cut was made, but it is now hard to find. It was exposed also in an older cut to the eastward through which the railroad formerly ran. At the Eagle road, about a thousand feet northwest of Wayne Station, but immediately northwest of the cut just mentioned, the railroad enters the hydromica, in which it continues over ten miles, the grade rising from 405 feet at Wayne to 546 feet at Malvern with summits probably 50 feet to 75 feet higher. At Frazer the summit of the hill is 560 feet; the railroad has descended to 490 feet, and is near the northerly foot of the hill, limestone appearing on the north within one or two hundred yards. Here the West Chester branch diverges southward, climbs the hill to a height of 584 feet, and crosses it to the ancient gneiss which underlies West Chester. The cuts of the Pennsylvania Railroad from Wayne westward afford abundant exposures. The rock is quite uniform; the following dips were obtained: Just below Valley Forge road (near Devon), strike N. 70° E. 90°; 200 feet west, N. 12° W. 87°; east of Devon Station, S. 5° E. 75°; half a mile above, S. 30° E. 85°; 200 feet above the last, S. 25° E. 85°.

At the northwest end of this cut there is for about a hundred feet the unusual dip of N. 45° W. 65°, followed by a small valley and another cut, strike N. 60° E. 90°; toward the west end of this cut N. 50° W. 60°, being almost a repetition of the former. Just below Berwyn Station, strike N. 45° E. 90°, just above strike N. 50° E. ± 90°.

Along the north foot of the hill the dips are usually S. E. 60° and upwards, agreeing closely with those of the limestone—*e. g.*, southwest of Howellville, Chester county, S. 25° E. 60°; north

of Paoli, S. 35° E. 75° to 90°; Frazer, S. 10° E. 65°, S. 25° E. 60°, S. 35° E. 65°; south of Glenloch, S. 30° E. 60° to 90°, S. 25° E. 70° to 80°.

The exposures along the West Chester branch present no special features. The border line between the mica schists and the hydromica is not distinct; the latter east and west of Kirkland Station strikes N. 60° to 75° E. 90°, but a half-mile north of Green Hill Station the mica schists are well exposed close to a small branch of Taylor's or Black Horse run. They dip quite regularly S. 23° E. 60°. The same rock forms bold bluffs further west along Broad run,[112] a small branch of Valley creek. The hydromica is not well exposed in this vicinity, but its border is probably but a little north of the southerly line of West Whiteland township, so that the hydromica has diminished in width to a mile and a half or less.

About a mile and a half further west Valley creek affords a good section, as does also the East Branch of the Brandywine one to two miles beyond (the two converging). On the former the hydromica may be seen with a vertical dip about three-quarters of a mile south of the Pennsylvania Railroad, while at and above McMinn's (now Grubb's) mill the mica schist dips S. 30° E. 60° and S. 25° E. 45°. On the East Branch the latter is very

[112] It may prevent confusion to state that there are at least three Broad runs in Chester county, the northernmost a small creek rising near Kirkland Station on the railroad from Frazer to West Chester and flowing nearly west into Valley creek (C^4, p. 9); the next a considerable stream rising in the hydromica schists south of Gallagherville and flowing southeast in a course which for four miles is remarkable for its parallelism to the general course of the Brandywine, from which in the four miles it is but little over one mile distant. This course is curved first eastward, then southeastward, the last being nearly the dip. This is the Brardley run of C^4, pp. 40, 70. The southernmost is in the southerly part of New Garden township, close to and nearly parallel with the Delaware State line.

"Extensive exposures of limestone occur along the northern edge of New Garden township in the banks of Broad run" (C^4, p. 59). If this is correct there is a fourth Broad run.

Valley creek is but little more definite, as two of the name head in the Chester Valley on the east and west sides of the divide which crosses the valley near Glenloch in the western part of East Whiteland township, the easterly flowing east and then north through the Valley Forge Gap to the Schuylkill, the westerly flowing west and then south into the East Branch of the Brandywine. It is this into which the Broad run referred to in the text flows.

Besides these there is Valley run, rising south of Caln Meeting-house, flowing eastward through the Chester Valley and through Beaver creek into the East Branch of the Brandywine.

boldly exposed close to Hawley's mill, S. 35 E. 45°, S. 40° E. 40°, S. 40° E. 65°, S. 70° E. 25°; while within 500 feet to the northwest the hydromica, striking about N. 50° E., dips vertically.

About a quarter of a mile above Hawley's mill and one mile above Valley creek, there is a small quarry in very quartzose hydromica on the right bank. The bedding is unusually regular. The rock contains small cubes of pyrite. Its strike is N. 50° E., dip 85° to 90° S. E.

About a mile above this, on the left bank, close to where the road to the east part of Downingtown crosses the creek, is a green hydromica schist N. 75° E., 85° to 90° N. W. This is close to the northwest corner of East Bradford township.

About three-quarters of a mile S. 30° W. of Hawley's mill, on the farm of Wilson Young, is a quarry in which the schist resembles more closely the mica schist than the hydromica, but with a dip of 90°, strike N. 45° E. About 500 feet south of this is an outcrop of dolomite colored green, probably by talc.

About three miles west of the East Branch, along Broad run, and about one and three-quarter miles south of Thorndale, is a high bluff of hydromica schist dipping S. 40° E. 70°. West of this is a distinct but small anticlinal in the hydromica from N. 40° W. 75° to S. 28° E. 55°, while a quarter of a mile north the strike is N. 60° E., the dip 90°. One mile south the mica schists, here heavy-bedded and hard, dip nearly S. ± 15°.

The localities mentioned in the last two paragraphs indicate that the usual nearly vertical dip of the hydromica and the low dip of the mica schists are not without exception.

On the West Branch of the Brandywine the hydromica schists may be seen well exposed south of Coatesville to beyond Modena on the northeast bank, dipping S. 25° E. 60°, S. 10° E. 55°, S. 45° E. 45°, S. 25° E. 50°, S. 30° E. 55°, S. 20° E. 45°, S. 45°, below which are the mica schists. The mica schists occupy the southwest bank from northwest of Modena southeastward, with dips S. 10° E. 55°, S. 35° E. 10° to 20°, S. 10° W. 20°, S. 20° E. 50°, S. 35° W. 20°, S. 80° W. 30°, S. 40° W. 20°. No definite structure could be made from these very irregular dips.

On the highland between lines south of Coatesville and of Pomeroy no trustworthy dips in the hydromica were obtained. The mica schist, however, is exposed, especially along the Strasburg

road, and here seems to dip S. ± 45° E.± 50° with much uniformity (one dip, however, was S. 10° E. 55°), but on the road from the Strasburg road to Modena, at a half-mile west of the former, S. 35° E. 10° to 20°; at five-eighths, S. 10° W. 20°; at three-quarters, S. 20° E. 50°.

The next gap is made by Buck run flowing south from Pomeroy. Here the line is near Newlin Station, north of Garrett's mill. At the mill the mica schists form a precipitous hill and dip S. 20° E. 35°. South of Newlin Station they are S. 50° to 60° E. 20°, one-quarter mile above S. 40° E. 45° on the right bank, S. 25° E. 35° on the left bank near the railroad bridge. On the same side, one-eighth mile above the grist mill near Newlin Station, convoluted mica schist dips S. 40° E. 60°. A quarter of a mile above the dip of S. 25° E. 35° near the railroad bridge, above (northwest of) Newlin, the hydromica appears dipping S. 50° E. 80°; a mile further northwest S. 45° E. 85°, then a half-mile from Pomeroy and not far from the limestone S. 35° E. 60°, S. 30° E. 50°, beyond which the limestone dips S. 20° E. 60°, S. 25° E. 60°.

West of Buck run exposures near the border are few and poor. One in the mica schist on Fawn run is S. 50° E. 30°; near Gum Tree N. 55° W. 35°. North of this, on the Highland road, hydromica schist, here unusually full of altered pyrite, is abundant. In West Fallowfield, near Hudson's grist mill on Officer's run, hydromica schist dips S. 45° E. 45° to 90°, but further west near Steeleville, on the Octorara, the rock fragments are of mica schist.

In Lancaster county the division line appears to be near Chestnut Level, where mica shists dip S. E. 30° to 40°, also near Fern-Glen Post-office, S. 35° E. 40°. On the Susquehanna, above and below Phyt's eddy, very compact heavy-bedded mica schists, dipping S. 30° to 35° E. 40° to 55°, make high cliffs.

If the distinction between the mica schists and the hydromica is a valid one, it is of no little importance to a proper comprehension of the geology of the region. The distinctions which I would draw may be summed as follows:

Mica Schists.	Hydromica Schists.
Structure comparatively coarse.	Structure very fine.
Quartz visibly intermixed and especially interlaminated.	Visible quartz in lenticular masses, very rarely interlaminated.

Mica Schists.	Hydromica Schists.
Feel rough and harsh.	Feel smooth and unctuous.
Lamination often curved and twisted.	Lamination smooth and regular (sometimes waved), except around the lenticular quartz, whose curves it follows.
Quarries into large blocks with parallel bedding or cleavage planes and roughly rectangular sides. Makes a fair rough building stone.[113]	The quartzose variety quarries into comparatively small pieces with more or less rounded surfaces. Almost worthless as a building stone. That free from visible quartz breaks into thin plates, is very soft and of almost no value.
Dips usually southeast and generally less than 40°.	Dips usually 70° and upwards, except on the northern edge adjacent to the limestone and except in its western part.
Feldspar often present macroscopically.	Feldspar rare and found in minute particles only and kaolinized.
Garnets often abundant. Pyrites very rare, disseminated.	No garnets detected. Pyrites in some portions, abundant in cubes altered in great part to limonite. The quartz full of cavities containing ferric oxide.

The dip is the most distinct feature, except in the Coatesville-Modena section and westward. Dr. Frazer seems to have noticed the difference of dip, but to have regarded it as of little significance.

On page 287, describing Willistown, he says: "The northern part of the township is filled with broad conchoidal mica schist containing much chlorite and milk quartz; . . . . dips vertical or nearly so." He then gives two dips N. 20° W. 80°, S. 15° E. 85°. "On the State road near George Hoskins, S. 35° E. 62°." This last is in the southerly part, in what I think the true mica schists, and illustrates the change of dip.

Describing East Bradford he gives dips apparently going southward: "Strike of these schists is N. 30° E. and the dip vertical. At the mouth of Valley creek the same rocks[114] dip S. 20° E. 40°

[113] The bridge which carries the Strasburg road over the West Branch of the Brandywine was built about 1820 of this stone, quarried in the vicinity, and is surpassed by very few road bridges in Pennsylvania. It has five arches.

[114] In my judgment the rocks having these diverse dips are equally diverse

(C^4, p. 292). . . . . In all cases above mentioned the rocks are chloritic in character." "On the eastern side of the township the character of the rocks is not chloritic, though there can be no doubt of the stratigraphical continuity of the beds"[115] (C^4, p. 293).

Describing West Bradford (pages 295, 296), the same change of dip may be noticed: "85°, 70°, 80°, vertical, 72°, vertical, a little further south . . . . S. 20° E. 40°, S. 40°, S. 20° E. 45°." "There can be little doubt that in these dips we have an anticlinal between the limestone valley of Chester (and the vertical dips immediately south of it) and the limestone belt here with the moderate southeast dips in the same schists just north of it."

My view would be nonconformity and that the schists are not of the same age. The Schuylkill section may prove instructive in this connection, comparing the east side with the west, the intervening distance being about a mile and a half for 3, half a mile for 4, and about a thousand feet for the others.[116]

	East Side.	West Side.
S.E.	1. Ancient gneiss.	1. Ancient gneiss.
	2. Rogers' Altered Primal.	2. Rogers' Altered Primal.
	3. Cambrian sandstone, almost undoubtedly continuous through Barren Hill and Willow Grove with 7.	3. Mica schist, in or northwest of which occurs (to the westward) Cambrian sandstone.
	4. Limestone, almost certainly continuous north of Marble Hall and Barren Hill with 6.	4. Limestone, mica schist.
	5. Hydromica schist.	5. Hydromica schist.
	6. Limestone of the Chester Valley.	6. Limestone of the Chester Valley.
		6½. To the westward mica schist.
	7. Cambrian sandstone.	7. Cambrian sandstone.
		7½. To the westward schistose and gneissoid rocks.
	8. Ancient gneiss.	8. Ancient gneiss.

in their character, as elsewhere described and nowhere better to be seen than here, the northerly steep dipping being soft, almost ductile, the southerly, gently dipping, being hard harsh quartzose schist.

[115] It is to be regretted that Dr. Frazer has not more fully described these chloritic rocks. Among the hydro mica schists I have seen no chlorites, and yet if I understand him aright, it is in the hydromica schist area that he found them abundantly. Dr. Frazer was one of the first, if not the very first, to call attention to the misnomer of the "talc schists" (*Am. Naturalist*, Oct., 1883) for rocks containing no magnesia.

[116] Except that 7 and 8 are concealed on the Schuylkill by the Red Sandstone, but outcrop both northeast and southwest.

All observed facts seem to agree with the hydromica schists lying in a synclinal (perhaps not simple) over the limestone, and may be recapitulated as follows:

First.—The limestone of the Chester Valley may be followed northeastward around the end of the hydromica and thence southwestward into Cream Valley.

Second.—The limestone in its turn is surrounded, except on the west, by Cambrian sandstone and that by the ancient gneiss.

Third.—The two northwesterly hills of hydromica strike into a limestone valley with nearly vertical dips, the limestone having similar strike and dip. No explanation seems possible but that the two were closely folded together, the hydromica overlying.

Fourth.—As already stated, limestone was exposed north of the trap dyke in Conshohocken in the nose of the hydromica schist hill, about twenty feet below the surface.

In considering the limestones, I have mentioned the fact that these hydromica schists bound the valley in Lancaster as they do in Chester county, and that west of Quarryville they seem to extend northward and the limestone to dip under them.

The Schists and Gneisses.

Excluding the Ancient Gneiss and the Hydromica Schist.

For convenience of detailed description the schists and gneisses may be subdivided as follows from the ancient gneiss as a starting-point, the first, and perhaps the third, occurring on both sides, the others on the southeast only:

1. Rogers' Altered Primal.
2. The Spangled Schists.
3. The Chestnut Hill Schists, including the highly garnetiferous schists and the sandy schists (whetstone schists). Prof. Rogers' second belt.
4. The harder, more plicated schists and gneisses to the eastward of the last. These may again be divided into:
   - *A.* Manayunk schists.
   - *B.* Porphyritic gneiss.
   - *C.* The more feldspathic schists and gneisses with much hornblende schist and gneiss, including the Fairmount-Leiperville-Chester gneiss.
   - *D.* The Frankford gneiss.
5. The schists between the North Chester Valley Hill sandstone and the limestone.
6. The schists, gneisses, etc., north of that sandstone.

The whole series of these rocks between the ancient gneiss of the Buck Ridge and its continuation southwestward, and the Delaware river from Trenton, N. J., to the southerly line of Pennsylvania, and, in western Chester county, over the whole area from the hydromica schists of the South Valley Hill southward, have been termed by Prof. Lesley, following Prof. Rogers, "The Newer Gneiss of the Philadelphia Belt."[117]

He regards them as belonging all to one system of sedimentary rocks, the oldest on the southeastern edge (Gray's Ferry), and as being the remnants of a mountain range of which the mica schists of LaFayette, on the Schuylkill, formed summits of ten thousand or fifteen thousand feet in height.[118]

In saying "The Newer Gneiss seems to occupy the whole field south of the belt of South Valley Hill hydromica slate in Chester . . . . county," I presume Prof. Lesley did not intend to include the ancient gneiss area, over three miles wide in the eastern part of the county and running to a point west of Northbrook, about halfway to the Lancaster county line, the continuation of Buck Ridge.

On the Schuylkill section these rocks were divided by Prof. Rogers into his first and second groups, by Mr. Hall into three, his second, the Manayunk schists and gneisses, including part of Rogers' first, and perhaps part of his second. Mr. Hall's name is convenient to distinguish the schists and gneisses which cover the greater part of the area, and which are so well and typically exposed at and near Manayunk.[119]

The differing views of geologists as to these schists and gneisses have been given, but the researches of Dr. George H. Williams[120] and of Mr. Frederick D. Chester[121] and Mr. C. B. Keyes[122] in the region to the south have thrown much light on the rocks in the adjacent Pennsylvania region.

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[117] *Final Report*, pp. 118, 128; *First Geol. Survey of Pa.*, I, p. 64.

[118] *Ibid.*, I, pp. 118, 119.

[119] These divisions, while serving a useful purpose in discussing the region, must not be regarded as typifying wholly distinct series of rocks, for in most of them strata may be found closely resembling the typical rocks of some of the others. Over large areas, however, the type rocks are very much more abundant than any other kind.

[120] The gabbros and associated hornblende rocks occurring in the neighborhood of Baltimore, Md. (*Bul. U. S. Geol. Survey*, No. 28).

[121] The gabbros and associated rocks in Delaware (*Bul. U. S. Geol. Survey*, No. 59; *Proc. Acad. Nat. Sci.*, Phila., 1884, p. 248).

[122] *Bul. Geol. Soc. Amer.*, 1891, Vol. II, p. 309, etc.

The studies of these geologists seem to establish the fact beyond question that in those areas igneous rocks have by dynamic metamorphism become more and more changed, chiefly by the well-recognized alteration of pyroxene into hornblende, and the development of a distinctly foliated character into what are known in the Philadelphia belt as hornblende schists and gneisses.

With this introduction it will be best to consider first the rocks nearest the ancient gneiss, then the limited areas of the porphyritic gneiss and the Fairmount and Frankford gneisses, leaving to the last the very large area outside of those mentioned.

It should also be noted that in this region it is impracticable, in the present state of our knowledge, to use the terms gneiss and schist in their strict petrographic sense. While there are true and typical schists, and equally characteristic gneisses, yet these pass the one into the other by insensible gradations. The terms therefore will be used more in a general than in a strict petrographic sense.

I. Rogers' Altered Primal.

The typical rock is thus described by Prof. Rogers: "Metamorphosed with characteristic white streaks of imperfectly developed crystallized feldspar and hard hornblendic material, with roundish specks of semi-crystallized feldspar;"[123] "remarkable for the regular parallelism of its lamination and bedding; the laminæ alternately light and dark, being exceedingly thin, many of them usually packing within the thickness of an inch. . . . . In some of the layers certain laminæ are studded with isolated crystallizations of hornblende."[124]

This description is graphic as the rock itself is characteristic. Its breadth is not great, but on both sides of the ancient gneiss, from east of the Schuylkill westward, it seems to be of constant occurrence. The rock is often plicated, sometimes minutely so. It is well exposed at the Schuylkill where it appears to be thicker than elsewhere. As Prof. Rogers notes, the feldspar occasionally occurs in rounded crystalline masses of considerable size and the rock approaches a porphyritic gneiss in aspect, but the feldspar is rather in nodules and not in crystals. Some beds, well shown in the

[123] Vol. I, p. 72.
[124] *Ibid.*, p. 68.

Stacker-Brooks quarry one mile north of Radnor Station, Delaware county, Pa., yield a flagstone. This quarry exposes the rock well, and in it occurred distinct pebbles of the ancient gneiss, the only occurrence in this region of pebbles in these rocks of which I am aware except in similar rock west of the Brandywine. The lamination and plication are shown in a photograph by Dr. Charles Schaeffer.[125] It is here in contact, with the limestone, and on the

FIG. 4.—Plicated gneiss. One mile north of Radnor Station.

southeast side of the latter, but on the northwest side the rock is not essentially different. The limestone appears to be less than forty feet in width.

It is possible that the Conshohocken diabase dyke, which about this point crosses it, or is in juxtaposition, may have caused some change, but at other points in the course of this dyke there seems to have been little or no effect on the adjacent rocks. The rule,

[125] Except the possible occurrence at the Queen Lane Reservoir, Philadelphia, and in the Avondale lime-tone hereafter noted.

however, is that this harder porphyry-like rock is next to the ancient gneiss, and it frequently forms a guide to the margin, as in southeast Willistown, near Westtown School, and on the Brandywine.

On the southeasterly side of the ancient gneiss it may be seen at the Schuylkill, but best in a quarry on the place of Dr. Williams, southwest of Rosemont; also near Westtown School, southeast of West Chester.

Prof. Rogers regarded this as equivalent to his lower primal slate of the North Valley Hill, but apparently all that can be certainly stated as to its age is that in this region it is the upper stratum of the ancient gneiss, or else the first overlying rock. It is evidently of clastic origin.

I have omitted this rock from the geological map because its narrowness would require it to be greatly exaggerated to be visible at all.

II. The Spangled Schists.

These, while probably but a variety, are well defined and important.[126] They form to the northeastward a narrow but characteristic belt northwest of the Chestnut Hill schists, from which they differ markedly. In Huntingdon Valley they lie southeast of the limestone and on the Neshaminy southeast of the Cambrian sandstone. The characteristic feature of most of the rock—namely, that the mica, instead of being all disseminated, is partly in separate curved imperfect crystals, as if it had been subjected to great compression, the crystals showing brilliant surfaces on exposure—is here well shown. Generally the crystals are quite imperfect, but sometimes nearly perfect. Feldspar, probably orthoclase, while frequently absent is sometimes present in large quantity. To the southwest the curved surfaces of the mica are large, when the term conchoidal mica schists, applied to them by Dr. Frazer, is most appropriate,[127] the rock on a cleavage surface presenting a series of rounded hills and hollows, with the mica particles parallel to the curving sides.

These rocks are usually quite schistose, but sometimes in heavy and solid beds, sometimes very micaceous, sometimes feldspathic, and sometimes hornblendic, but invariably the characteristic min-

[126] *Second Geol. Survey of Pa., Annual Report*, 1886, p. 1592.
[127] C⁴, p. 287.

eral, whether mica, feldspar or hornblende, is in more or less distinct crystals through the rock. The feldspar crystals are often large, but usually not distinct in form, resembling rather rounded pebbles, but almost always with single smooth cleavages. In certain varieties these feldspar masses weather out while the ground mass remains intact, forming a rock full of holes, well shown north of the ancient gneiss west of the East Branch of the Brandywine, southwest of Copesville. The mica crystals are sometimes very distinct and abundant, with perfect cleavage, but usually with curved surfaces; more frequently they are indistinct, but a fracture of the rock gives always a succession of rounded elevations and depressions, usually small, but sometimes two or three inches across, with much lustre.

More rarely hornblende appears, not scattered through the rock in minute particles, but distinctly crystallized, sometimes on the cleavage or bedding plane like the tourmalines of the Cambrian sandstone, sometimes, as well shown on the west bank of the Brandywine just below the mouth of the East Branch, in distinct imbedded crystals.

This porphyritic character seems, however, to be not confined to the lowest rocks of the series, as, at least in one instance, the rock above the Cambrian sandstone is of the same character. This is in Cream Valley, one mile nearly north of Radnor Station, and a quarter of a mile west of the Montgomery-Delaware county line.

The northeasternmost point at which these schists are well exposed is close to the Pennypack creek, east of the Bound Brook Railroad, though they appear as far east as the Neshaminy. Near the Pennypack they are more compact and harder than elsewhere and are very dark and argillaceous-looking. At Paul Brook Station, in a well, the same schists were found, much decomposed, full of large garnets. They form the northwest flank of the hill bounding Huntingdon Valley on the south, about an eighth of a mile southeast of the limestone. They dip quite regularly S. 20° to 30 E. 60° to 70°, and are bounded southeast by the Chestnut Hill schists, as usual much plicated and nearly vertical. They contain garnets in some strata, the garnets usually much larger and not nearly so numerous as in the typical Chestnut Hill schists.

They continue flanking the hill to its termination near Jenkintown, southwest of which they again appear southeast of the Cambrian

sandstone of Waverly Heights. They may be seen on the westerly slope of Chestnut Hill, on Paper Mill lane, and on the Schuylkill close to the LaFayette serpentine, also at Rosemont, between the serpentine and the ancient gneiss, dipping S. 45° E. 50°. Here the Chestnut Hill schists east of it are not very garnetiferous, but sandy and approaching whetstone. On the Roberts' road, the nearest exposure, the latter dip S. 40° E. 80°; further southeast, S. 57° E. 57°, S. 48° E. 50°, S. 45° E. 62°, S. 50° E. 70°, with some irregular, as E., S. 80° E., S. 70° E.

It is possible that these belong to the spangled series and not to the Chestnut Hill. Typical Chestnut Hill schists occur further east, not well shown, near the Pennsylvania Railroad, owing to deep decomposition, but very clearly both to the north and south.

Southwest of Rosemont the spangled schists are exposed on the Roberts' road, and here one stratum is very feldspathic and crystalline, almost a granite. It has, however, the same relation to the ancient gneiss as the schists at Rosemont.

At Darby creek they are prominent, here lying within 200 feet southeast of the ancient gneiss and northwest of the serpentine. Both the muscovite and the orthoclase are in a more crystalline condition than elsewhere, except perhaps southwest of Rosemont; the different strata vary greatly, the most crystalline muscovite occurring in an argillitic variety of the schist.

Westward of Darby creek exposures are very few, and I am not aware of any outcrop that can be clearly recognized. On the Brandywine, however, a porphyritic gneiss, with hornblende crystals in place of mica, just east of the ancient gneiss probably takes its place.

About two miles west of the forks of the Brandywine, on the State road, near Pocopsin Inn, and between the ancient gneiss and serpentine, it is well exposed, being here very feldspathic. It dips nearly E. 10°, and apparently overlies the serpentine. The ancient gneiss is here not over a quarter of a mile in width, and on the northwest side similar schists occur. A mile to the southwest, the ancient gneiss ends apparently in a large outcrop of serpentine and enstatite (Newlin corundum locality), beyond and on both sides of which is a great area of mica schists. Northwest of the ancient gneiss these extend to the Schuylkill, narrowing greatly.

Because of this narrowing they will be discussed from the Schuylkill westward.

As has been stated, the sequence of the rocks on the west side of the Schuylkill near Conshohocken is: Southeast—ancient gneiss, Rogers' Altered Primal, garnetiferous schists, limestone. Northwest—hydromica schist, but in the midst of the limestone schists appear. The contact on the southeast is concealed. The limestone dips S. 28° E. 74°; about 300 feet northwest limestone again appears, dipping about 70° to 80° N. W. If dips so steep as these are trustworthy we have here an anticlinal of limestone.

A little east of this, on Aramink creek, the contacts of the gneiss, the altered primal and the garnetiferous schist—the latter here, and here only, very closely resembling the typical Chestnut Hill rock—may be seen. The dips are very uniform and agree well with those of the limestone: Gneiss S. 20° E. 73°; altered primal S. 20° E. 85°; schist S. 25° E. 80°, while on the River road there are dips in the schists of S. 61°, S. 60° E. 86°, and immediately southeast of the schists a sandy white rock, breaking into small angular fragments much resembling the Cambrian sandstone, which outcrops on the opposite shore of the river at Spring Mill.[128]

These outcrops are near the mouth of Cream Valley, a very straight narrow valley, referred to on p. 216. At this point the summit of the gneiss hill is over 400 feet above the floor of the valley, while the opposing hill (hydromica schist) is between 200 and 300 feet, the summits being less than a mile apart.

The schists may be found thence westward on the northerly slope of the gneiss hill. On the Gulf road, and westward, serpentine and steatite appear in the schists.[129] On Montgomery avenue, 1.5 miles from the Schuylkill, the Cambrian sandstone appears in or close to them.

About a half-mile west of Montgomery avenue, large masses of these schists, full of large garnets, appear near Gulf Creek on the land of Mr. Joseph E. Gillingham. From this westward they are readily detected at short intervals. Close to the Delaware-Montgomery county line, the typical sandstone was exposed in the bed

[128] A mile and a half distant, the river for that space flowing at the base of the ancient gneiss parallel to the strike and over the line of strike of the limestone and sandstone.

[129] The northerly Radnor belt (*Proc. Acad. Nat. Sci.*, 1878, p. 402).

of an affluent of Gulf creek, with the schists apparently on both sides of it, certainly on the southeast side. About .4 of a mile west of this was the Stacker-Brooks quarry in limestone and schistose gneiss, some layers answering to the description of Rogers' Altered Primal, much alike on both sides of the limestone, except that on the south side some layers of the rock were more slaty and quartzose, while on the north side the porphyritic aspect was more developed. Both sides and the limestone were plicated. About an eighth of a mile nearly due south of this quarry the sandstone was exposed in a lane on the west line of Judge Hare's property.

About .6 mile west of the quarry and south of the Eagle road,[130] west of the Radnor and King of Prussia road, large masses of the schist may be seen containing staurolite in addition to the garnets. The schists were exposed in a well south of this on the property of E. A. Schmidt.

In a quarry on land of Francis Fenimore, a quarter of a mile north of St. David's Station, they are unusually well exposed, dipping N. 25° W. 70°, N. 34° W. 75°, while the hydromica schists on the north are S. 10° E. 90°, S. 20° E. 60° to 80°, S. 25–30° E. 70°. North of Wayne they are poorly exposed, but shown to be at least 400 to 500 feet in breadth, probably more than to the eastward. Here, apparently in these schists, both on Gulf creek and in the cut of the railroad, the typical Cambrian sandstone appears.[131]

[130] The Mattson's Ford road follows the valley from the Schuylkill to the Delaware county line. It then bears more southwestwardly and ascends the ancient gneiss hill, crossing a serpentine outcrop (the Radnor-West-Chester belt, not the northerly belt just mentioned), to Radnor Station, while about .2 m. to the north the Brooke's Mill road continues up the valley ending in the Radnor and King of Prussia road. On this road, about .1 m. north, the Eagle road begins and continues up the valley.

[131] Contrary to Dr. Frazer's opinion, I think there is no difficulty in tracing the border line between the hydromica schist and the mica schists which lie to the southward, that is if I understand him correctly. "Throughout an area widening from the east from one mile near Eagle Station to fourteen miles or more along the Octorara creek, and touching the northern outcrop lines of most of the limestone and serpentine patches which extend along this belt, there occur thin mica schists . . . . some of them are garnetiferous. . . . . Within this triangular area . . . . are irregular included areas of more or less chloritic rock and some argillitic or hydra-mica-schists. It was intended to separate these areas from the general mica-schist region and from each other, but this attempt when reduced to paper had to be abandoned, so impossible to suppose as the results of natural divisions were the boundaries thereby produced." C^4, p. 216.

Eagle Station was at the crossing of the Conestoga turnpike by the Pennsylvania Railroad, about .5 m. east of Devon Station. This point is about .3

This is about four miles from the Schuylkill. Westward they are almost continuous and widen greatly, though usually occupying low ground and therefore much concealed.

In Easttown and Willistown townships, in Chester county, near the headwaters of Crum creek, eleven miles from the Schuylkill, they are poorly exposed in connection with the serpentine. On the road next south of the State road three approximatively parallel outcrops of serpentine may be seen, with two and perhaps three outcrops of trap (diabase) and with the garnetiferous schists in place both to the northwest and southeast, and with garnetiferous schist fragments between the serpentine outcrops. On the road leading to Green Tree, the schists may be seen on both sides of the serpentine, while on the road to Malvern, half a mile westward, they occupy a space of some 2,000 feet between two outcrops of serpentine. Trap, probably the diabase of the Conshohocken dyke, occurs distinctly north of all these serpentine outcrops, and to a less extent among them, but none of the outcrops of any of the rocks, except the serpentines, are favorable for observation.

North of West Chester, the schists have become nearly or quite a mile in width. Here they do not appear between the serpentine and the gneiss, but only north of the serpentine. Near the serpentine they contain garnets and staurolite, and throughout garnetiferous strata are not uncommon. The dip is almost uniformly to the southeast and not steep—*e. g.*, one-half mile west of Green Hill Station, S. 23° E. 60°; on High street, near Wrangle Schoolhouse, S. 20° to 30° E. ± 50°; on the north branch of Broad run, in the southwest corner of West Whiteland township, S. 20° E. 55°, but a little higher up the creek they strike N. 60°

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mile north of the ancient gneiss hill and about 1.5 south of the southerly border of the Chester Valley limestone, the hydromica schists lying on both sides of the railroad, the mica schists not exposed, the ground south of the railroad being low. It is clear, therefore, that Dr. Frazer means to include the soft unctuous hydromica schists, but as these occupy to the westward a comparatively narrow belt, the harder mica schists must be included. This is confirmed by the fact that the latter are frequently garnetiferous, the former rarely if ever so. The distinctions between the chloritic and non-chloritic schists I have been unable to recognize. Except in small quantity among the serpentines, and except a narrow stratum near Mortonville, I doubt whether there is chlorite schist, properly so-called, in the region except as a comparatively rare occurrence as in quartz masses near Gum Tree. The line of demarkation between what I have termed the mica schist and the hydromica is clear, sharp and easily to be recognized wherever the exposures suffice, and such are not few.

E. and are nearly vertical. They are exposed in this vicinity in bold bluffs. A very short distance to the north the soft hydromica schists may be seen dipping vertically.

In this vicinity there appears among the schists a hard compact mica and hornblende gneiss much resembling some of the ancient gneiss, but more schistose. It appears on New street, northeast of West Chester in abundant loose masses, and also in place. Its strike is nearly west-southwest, dip about 90°. This is in West Goshen, about a quarter of a mile east of the East Bradford township line. North of it are loose masses of serpentine, but none of it was seen in place. On the west side of the township line, or perhaps on the line, and west of it, this gneiss seems to form the centre of a hill of about 175 feet in height, quite narrow and about half a mile long. On both its flanks are the schists. A road cutting exposed the westerly nose of this hill, showing a narrow synclinal of the gneiss, including a stratum two feet wide of steatite, overlying which were mica schist and quartz, much plicated. Nearly on the strike of this hill, and about 500 feet southwest, is a lower, less abrupt hill of schists, including two outcrops of limestone (Cope's quarries). They lie about S. 50° W. and S. 65° W. from the gneiss. The limestone and schists in the southerly and best exposed outcrop strike S. 40° W., dip N. 35° to 45° W. 65°. The schists forming the north wall are garnetiferous, spangled and contain interlaminated quartz and also feldspar nodules. The limestone is but about forty feet wide. The south wall is a porphyritic schistose gneiss, but, as Dr. Frazer suggests, probably more recent than the ancient gneiss and made up of fragments of it.[132] The other outcrop, perhaps 200 feet to the north, is insignificant, showing only the south leg of an anticlinal, with traces of the arch. The adjacent rock is not exposed in place, but the soil is full of schist fragments.

To the northwest of Cope's quarry is a hill extending west-southwest to the Brandywine. This, as shown by fragments in the soil and by the exposures on the Brandywine, is of the harder feldspar and hornblende gneiss which forms the high hill east of Cope's. The trap dyke extends along its slope near the summit, but on the Brandywine it is on the southerly side of the small valley which separates this hill from that in which Cope's quarry is. A meas-

[132] C⁴, p. 294.

urement of this gneiss about .2 mile northwest of Cope's quarry just north of the trap gave a strike N. 40° E. nearly vertical. Northwest of this gneiss the schists again appear and near Copeland Schoolhouse contain thin layers of talc schist.

Cope's quarry is about a mile northeast of the East Branch of the Brandywine, on which the rocks are unusually well exposed. At the State road crossing, three miles southwest of West Chester, and for some distance above it, the ancient gneiss is seen. The next roads to the north are the Strasburg road, running westward from West Chester over the gneiss, and a short curved road diverging northwestwardly from it and converging to it along Black Horse run, laid out to obtain better gradients. The ancient gneiss is exposed on these roads also. The two unite at the crossing of Black Horse run, not far from Cope's quarry, and ascend the low hill on which the inn stands. This is of varied rock, chiefly a hard but schistose feldspar and compact hornblende gneiss, much of it decomposed. There are decomposed schists with it, probably the hornblende rock altered, and in seams in these a compact talc (?) known as "indurated talc." This rock does not resemble any other of the vicinity, and is probably intrusive, or perhaps the schists with intrusive hornblendic rocks (altered diorite?) altering them. On the east slope of the hill schists strike N. 60° E., dip uncertain. On the west slope, the hard gneiss strikes N. 40° E., dip uncertain. Close to the Brandywine, the Strasburg road makes a détour upstream to avoid a bold cliff on the right bank known as Deborah's rock. The rock forming this cliff strikes N. 50° E., dip about 90°; it is very hard but somewhat schistose mica and hornblende gneiss, and belongs, I believe, to the schistose series and not to the ancient gneiss. At Copesville, where the Strasburg road crosses, the schists are well exposed in high cliffs. They are quite micaceous and contain kyanite and garnet, and more rarely menaccanite with feldspar in porphyroidal masses; some layers are less micaceous. A hard gneiss with considerable masses of feldspar occurs further north. Dips here are S. 50° E. 40°, S. 30° E. 50°, S. 45° E. 45°. Some of the gneiss is studded with isolated crystals of hornblende. These rocks, as pointed out by Dr. Frazer, resemble strongly the rocks near the Delaware northwest of Chester.[133]

[133] C⁴, p. 61.

Three-quarters of a mile northwest of Copesville, Valley creek, flowing nearly south, empties into the Brandywine. On it at McMinn's mill, or Grubb's mill (Talcose Post-office), the mica schists dip S. 25° E. 45°, and just above S. 30° E. 60°. Three-quarters of a mile above McMinn's mill, the hydromica schists are met, the strike about southwest, but somewhat irregular, the dip vertical or nearly so.

Returning now to the East Branch of the Brandywine, the mica schists may be observed just above the mouth of Valley creek, dipping southeast about 60°. A mile above is Hawley's mill. On the left bank, high steep cliffs of the mica schists form a prominent feature, on the right bank they are also exposed, though not so prominent. They dip S. 40° E. 40°, S. 40° E. 65°, S. 35° E. 45°, S. 70° E. 25°. Less than three hundred feet above, the hydromica schists appear with their characteristic features, striking about S. 45° W., dip vertical or nearly so.

It should be noted that a line connecting Cope's limestone quarry with the range of quarries among which are the Poorhouse quarry and the Embreeville quarry would pass a little north of Copesville. In C⁴, p. 58, it is stated that there are signs of limestone on the East Branch of the Brandywine a little north of Copesville. I could find no outcrop; the contours, however, very distinctly indicate the continuance of the limestone, the creek itself following its strike for a half-mile at nearly 90° from its general course and a well-marked valley occupying the line west of the Brandywine. On the south side of this valley a road has been constructed diverging northwardly from the Strasburg road close to the Brandywine and entering it again a mile beyond Marshallton, to avoid a very high hill of the schists over which the old road passes. On the Strasburg road schists only can be seen (except trap) poorly exposed, dipping south-southeast, but on the newer road mica schists are well exposed, dipping S. 30° E. 50°. On this road, a little over a half-mile from the Brandywine, is the limestone quarry of George March. No contacts are visible, but south of the quarry and within 100 feet are quantities of schist fragments, two very large, which may be in place. Its strike is N. 40° E. A quarter of a mile north of the quarry there is an exposure in a lane on Ingram's property; the rocks are quite varied here, some layers being micaceous, some highly feldspathic, and some horn-

blendic. They strike from N. 80° E. to E. and dip 60° and upwards southeast, or toward the limestone. A quarter of a mile west of this is an abandoned limestone quarry (Moses Woodward's), south of which are schists poorly exposed. Three-quarters of a mile westward is the road to Gallagherville, near the junction of the newer road with the Strasburg road. Here in the schists there is a considerable outcrop of coarse pegmatite. The adjacent schists dip steeply to the northwest, and a variety with large garnets is precisely the rock of Fenimore's quarry, north of St. David's, Radnor township. Close by is another abandoned limestone quarry (Moses Bailey's), south of which is garnetiferous mica schist, imbedded in which was found a pebble-like mass of an older rock, probably ancient gneiss. This schist strikes N. 50° E. and is nearly vertical; a quarter of a mile south the schists dip S. E. ± 70°.

Half a mile southwest is the Poorhouse limestone quarry, by far the largest of the series. Here all the indications are that the schists both underlie and overlie the limestone. The dip being very low, 0° to 15° S. E., an overturn is incredible. North of the quarry decomposed gneiss and schists with quartzite bands dip S. 40° E. 45°, becoming steeper to 65° southeastwardly, while mica schists overlie conformably.

If we take a section line, west of Copesville, that is about midway between the East Branch and Broad run, we find the ancient gneiss well exposed on the West Branch of the Brandywine at Seeds Bridge, southwest of which it forms Brag Hill. On the westerly border of East Bradford, about three-quarters of a mile N. 15° W. of Seeds Bridge, is a plicated sandy schist with hornblende and mica gneiss, dipping about N. 45° W. 10° to 50°, and a quarter of a mile further a porphyritic, argillitic schist, in much of which the feldspar crystals or masses have weathered out, leaving numerous cavities. It forms a small hill, and strikes N. 50° to 70° E. vertical. West of this is a hill of the distinctly spangled schists, here containing much feldspar, hence a gneiss, dipping N. 45° W. 15°. Northward the schists continue, and in them, south of the Strasburg road, is trap which extends eastward probably two miles, and in line with that northwest of West Chester, near Black Horse run. It is probably the diabase of the Conshohocken dyke. North of Marshallton, the

schists dip S. 45° E. 60° on the southerly border of the limestone valley, north of which on this section-line no good exposures were seen, but to the eastward are the gneissoid schists north of March's quarry.

We come next to the most interesting section of this belt, viz., that north and south of Northbrook.

Beginning south of the ancient gneiss, here very narrow, we find going northward, the distances given being those of the outcrops noted:

Approximate Distance.	*Dip.*		
	10° E.		Spangled mica schist and granulite close east of and apparently overlying serpentine, State road, west of Pocopsin Inn. (Southeast of this other schists cover most of the region to the gabbro of Delaware.)
± 300′	S. 70° E.	30°.	Schists and gneiss, some highly feldspathic, some not; with talc and serpentine. This was the most satisfactory dip and about an average of a considerable exposure, but for a short distance the dip increased to 90° and was then 70° N. W.; this was south of the gentle southeasterly dips.
1,900′	N. 15° W.	75°.	Ancient gneiss, near northerly foot of hill.
2,600′	S. 40° E. Steep northwest irregular.	40°.	Ancient gneiss on the Brandywine east of Northbrook; two dips close together.
2,600′	N. 20° W. N. 70° W.	25°. 67°.	Schists on right bank of the Brandywine west of Northbrook, and to the westward enstatite and serpentine.
3,000′	± 0° to 45° ± N. W.		Schists on left bank west of Northbrook, very irregular.
1.5 m.	N. 45° W.	15°.	Spangled mica schists with much feldspar northeast of Trimbleville.

Approximate Distance.		*Dip.*		
1.75 m.	S.	45° E.	± 70°.) 90°.)	East and west of Broad run, south of the road next south of Strasburg road and close south of limestone.
2.5 m.	S.	± 45° E.	0°.) 20°.)	Limestone and mica schist overlying Poorhouse quarry.
2.6 m.	S.	40° E.	45°.) 70°.)	Schists north of Poorhouse quarry.
3.25 m.	S.		15°.	Heavy bedded schists on Broad run, a half-mile northeast of Romansville.
4. m.	S.	30° E.	90°.)	Hydromica schist on Broad run,
	S.	40° E.	70°.)	one mile north of Romansville.
6.25 m.	S.	± 60° E.	± 70°.	Limestone of the Chester Valley.

We have here apparently the schist resting upon both flanks of the ancient gneiss, with comparatively gentle dips from it and very close to its westward termination, no trace of it being visible one mile to the westward, the schists on both sides seeming to unite. Unfortunately, westward there are no good exposures, though abundant decomposing schist fragments are visible.

It would seem, therefore, that these rocks must be the first overlying the ancient gneiss. If such is the fact, and the same schist overlies both flanks, then it is impossible that these should be more recent than the more easterly mica schists, and equally impossible that there can be a profound fault between them and the ancient gneiss. From the occurrence in them of the limestone and of the sandstone, it seems most probable they are of Cambrian age. In this section there seems to be no trace of the subdivisions seen along the Schuylkill. On the contrary, while the mica schists and gneisses characterize the region, the former are most abundant, varying somewhat, mostly from more micaceous to more quartzose varieties, but not in distinct belts or areas, and almost free from other minerals.

Before considering these schists in their westerly and southerly continuation it will be best to discuss schists of somewhat similar character on the southeast of the ancient gneiss area.

III. The Chestnut Hill Schists.

Second Group of Prof. Rogers.

These lie between the spangled schists and the Manayunk schists, and have been so thoroughly discussed by Prof. Rogers, Mr. Hall and others that but a brief notice of them is necessary. They are thus described by Mr. Hall: "Characterized by the serpentines;[134] soapstone; silvery micaceous garnetiferous schists; light-colored thin-bedded sandy gneiss with disseminated light-colored mica in minute flakes."[135]

One of the most definite characteristics is thus well described by Prof. Rogers: "The rock breaking into long narrow chunks, comparatively smooth on their sides, but excessively ragged on their ends; a style of fracture strongly resembling that of half-rotted fibrous wood."[136] They are frequently very garnetiferous, much more so than any of the others.

In the *Final Report*, Vol. I, p. 125, it is stated that this group ends in a point at Jenkintown, eight miles east of the Schuylkill.[137]

While the peculiar wood-like schist, whether garnetiferous or not, is very well marked and characteristic, some areas of the belt as laid down by both Prof. Rogers and Mr. Hall contain rocks very hard to distinguish from those of Mr. Hall's Manayunk group. Mr. Hall states that no dividing line can be drawn. West of the Schuylkill he suggests Mill creek as the dividing line, but the gneisses immediately northwest of this stream are the hard gneisses of the Manayunk belt. The Wissahickon, the Schuylkill, and especially the Schuylkill Valley Railroad cuts give good sections, but no dividing line. Further southwestward the very garnetiferous

[134] Mr. Hall thinks the serpentines, with perhaps a few insignificant exceptions, confined to those rocks or overlying them in synclinal basins. C^5, p. 13 *et seq.* I have given elsewhere my reasons for doubting this (*Proc. Acad. Nat. Sci.*, 1890, p. 95 *et seq.*).

[135] C^6, p. 71.

[136] *Geol. of Pa.*, I, p. 71.

[137] This does not accord with my observations. It is well exposed in a quarry on the Pennypack creek south of Huntingdon valley, the spangled schist occurring as usual on its northwest side, dipping S. 30° E. 70°, while the Chestnut Hill schists are much plicated and apparently nearly vertical. This locality is four miles east-northeast of Jenkintown. The spangled schist is plainly visible on the Neshaminy southeast of Oakford Post-office, six miles further. There is at this point no evidence whether or not the Chestnut Hill or Manayunk schists flank them—there are no rock exposures.

This seems also not to accord with the theory that all these rocks are sheared by a fault diagonal to the strike (*Final Report*, I, p. 125).

variety, so abundant from Cobb's creek northward, gives place to a highly quartzose non-garnetiferous schist, a whetstone. In this section the rock, where entirely decomposed, may be traced by abundant masses of white quartz, weathering yellow. This may be seen in place in the schists on the Gulf road southeast of the Roberts' road, Bryn Mawr. Curiously the apparent southwesterly termination of this area of these schists, which is near Marple Schoolhouse, near the road from Newtown Square to Palmer's mills, is marked by an unusually great outcrop of the quartz.

In these schists kyanite and staurolite are not uncommon, while garnets constitute sometimes a considerable portion of the rock.

IV. The Porphyritic Gneiss.

About four miles from the ancient gneiss, measured along the Schuylkill, which from Spring Mill flows nearly on the line of dip, is the belt of porphyritic gneiss, a hard rock the limit of tide-water before the Fairmount dam was built. The channel was obstructed by the rock forming a rapids known as the Falls of Schuylkill, a name which that part of Philadelphia still retains. It is, at the Schuylkill, not over a quarter of a mile in breadth, and is not visible northeast of Laurel Hill, but it widens rapidly westward, extending at the Lancaster turnpike, 2.5 miles from the river, from the crossing of the Pennsylvania Railroad below Overbrook to Wynnewood, a distance of 2.25 miles, or 1.7 miles across the strike. It is well exposed on Cobb's creek, less so on Darby creek. It can be seen in quarries in the vicinity of Morton, but it apparently does not reach Crum creek.

Just on the northwestern edge of the porphyritic gneiss at the Schuylkill, that is about .2 mile above the Park bridge at the Falls, is a quarry, not recently wrought, in a rock showing the variety of, and rapid changes in, the gneiss of this region. Not over two or three hundred feet in linear extent and less on the strike, the following varieties occur:

Nearly white, fine-grained, chiefly oligoclase and quartz, with a little biotite and tourmaline;[138]
Quartzose biotite schist, nearly black;
Muscovite gneiss, fine-grained, light gray;
Hornblende gneiss, some of the hornblende passing into epidote;

[138] Determined by Mr. Goldsmith.

A gneiss nearly black in color, containing much black mica, probably biotite, passing into a black mica schist;

Pegmatite, chiefly of a reddish flesh-colored feldspar, with tourmaline.

This porphyritic gneiss has much to suggest an igneous origin; much of it is a true augen-gneiss. Its best exposure is that made by Cobb's creek, which flows through it by a deep valley. If igneous, we ought here to find in its width of two miles some unaltered rock and probably an increase in gneissic or schistose structure from the centre toward the edges, but we do not. On the contrary, it seems to alternate with mica schists containing staurolite, garnet and kyanite, or to include one or more areas of them, and the hardest and most crystalline rock is near the edges—*e. g.*, northwest of Sixtieth and Market streets, Philadelphia, and on Cobb's creek 500 feet south of the Haverford road, where that road going southeast turns east and leaves the creek. It has a fine-grained mica feldspar base in which are numerous evenly distributed crystals of feldspar, apparently orthoclase, always twinned, and usually, but not invariably, with their axes parallel. These crystals are firmly attached to the base, so that crystal forms are not seen, only sections upon fracture. They are from an eighth of an inch or less up to two inches in length.

The granite of this belt differs in aspect from that of the rest of the region. It occurs in large quantity. It is a coarse pegmatite, chiefly a flesh-red feldspar, sometimes more than flesh red, with a chalky-white feldspar and with very little quartz and mica, the latter sometimes in thin films and sometimes in small separate crystals. There is also true graphic granite, and some that resembles more a breccia of quartz and feldspar. In the cut of Lansdowne avenue, Philadelphia, it appears to be in dykes cutting the gneiss, or to be filling sharply defined veins. Toward Darby creek in this belt occurs much hornblende rock not containing the feldspar crystals. Microscopic examination by Dr. Bascom shows this to be a gabbro diorite. With this exception the rock is remarkably uniform over its whole area, the variation being almost wholly in the size of the feldspar crystals. The finer varieties make a very good building stone, and even the coarser are used.

This rock appears not to have been seen by the geologists of the Second Survey.[139] It seems to resemble very closely the augen-

[139] C[6], p. 27.

gneiss near Bedford, N. Y., described by Dr. Luquer and Dr. Ries.[140]

The Fairmount Gneiss.

This name has been applied to the rather fine-grained muscovite-microcliu-gneiss which forms the hill at Fairmount, Philadelphia, exposed only there and on the opposite bank of the Schuylkill, and along Crum and Ridley creeks near Chester and in that vicinity. On the west side of the Schuylkill it formed a low anticlinal, dipping under mica schists in both directions. The southeasterly dip may still be seen on the Pennsylvania Railroad; the northwesterly was exposed during the construction of the tunnel carrying the tracks of the New York branch under the main line, near Thirty-sixth street. The gneiss is here of very limited extent. On Crum and Ridley creeks what appears to be the same rock is well exposed, and has been largely quarried. Here the dip (cleavage?) is steep.[141]

This rock yields the most valued building stone of the region. The quarries on Ridley and Crum creeks are still yielding large quantities of fine building and curb stone, while that of the Fairmount quarries, until the advance of the city closed them, was much sought for.[142]

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[140] *Am. Geologist.* October, 1896, XVIII, p. 239.

[141] Mr. Hall (C[5], pp. 2 and 59, etc.), thinks the dip to be gentle and to the northwest and to be indicated by what are known to the quarrymen as beds.

[142] It is strange to find in the summary of the *Second Geol. Survey* a sweeping condemnation of this gneiss: "The Philadelphia lower subdivision . . . . " from "Gray's Ferry to the mouth of the Wi-sahickon. . . . . very few solid beds can be found and the surface stone is worthless. Even where quarries have been opened, the undecayed stone can only be used for the roughest building purposes . . . . . But among the gray micaceous gneiss beds and mica slate beds occur numerous beds of hard hornblende-gneiss, which is a good quarry stone and stands well" (p. 122).

In the following important structures the Fairmount gneiss was used for face stone and it would have been very much more largely used but for the fact that its outcrop was in part taken into Fairmount Park, in part by the Pennsylvania Railroad, and the remainder built upon.

The Church of the Redeemer, Bryn Mawr; Bryn Mawr Station; Ardmore Station; the residence of Mrs. Wheeler, Bryn Mawr and that of Mr. James R. Whitney; that of Mr. John C. Wilson, northwest corner Thirty-fifth and Powelton avenue; that of Mr. Field, southeast corner Thirty-sixth and Powelton avenue; that of George W. Blabon, Twenty-second and Tioga streets; St. Martin's Church, Radnor, Pa.

These and many others were constructed of the Fairmount stone and show no signs of decay.

The stone from the quarries on Crum and Ridley creeks has been used for nearly a century. The size of the quarries shows the immense quantity of stone removed. By far the largest proportion of this was used for face stone and curbing.

From the quarries on Crum and Ridley creeks was obtained the stone for the old Market Street Bridge, the new Baltimore & Ohio Railroad bridge across the Schuylkill in Fairmount Park, the bridge of the Trenton Cut-off Railroad over the Schuylkill below Norristown, and many other important structures, none of which show signs of deterioration.

The fine stone arched bridge of the Reading Railroad over the Schuylkill at the Falls was constructed over a half-century ago of the porphyritic gneiss, quarried near by, and is in perfect condition to-day.

Comparatively little of the hornblende gneiss has been used, except for road material, and except that of the Frankford and Rittenhouse lane (McKinney's) quarries, in which some hornblende occurs, though hardly in sufficient quantity to make it a hornblende gneiss.

The Frankford Gneiss.

This rock has the abnormal strike of nearly east and west. Its chief exposures are at Frankford, at Wayne Junction, Germantown, and at McKinney's quarry on the Wissahickon. It is a highly feldspathic gneiss containing but little mica (chiefly biotite, var. lepidomelane) and hornblende, very hard yet readily wrought, forming a valuable building stone.

At a time when all the rocks of the region were deemed undoubtedly sedimentary, the late Prof. H. Carvill Lewis asserted his belief that this was an altered intrusive dyke.[143]

The quarries at Frankford and McKinney's are noted mineral localities.[144]

The Manayunk Gneisses and Schists.

There remain to be described the mica schists and gneisses which cover the remainder of the area between the ancient gneiss and the Delaware, which are not distinctly separable into belts or areas. They are of somewhat varied character, but are typified by Mr. Hall's Manayunk belt, so called from the excellent exposures near that part of Philadelphia. He describes it as containing gray schistose gneiss with garnets, beds of hornblende slate and fine-grained sandy gneiss.[145]

[143] *Nature*, October 8, 1885, p. 560.
[144] *Proc. Acad. Nat. Sci.*, April 26, 1892, pp. 178, 179.
[145] C[6], p. 2.

FIG. 5.—Gneiss, Roxborough Avenue.

They contain few garnets compared with the Chestnut Hill series; toward the eastward, hornblende schists are more abundant, likewise feldspar. A prevailing feature is the sharp folding of the rock, the plications being numerous and great. Fig. 5 is from a photograph taken by Dr. Schäffer on Roxborough avenue near the Wissahickon, Philadelphia.

As stated by Mr. Hall and by Prof. Lesley the subdivisions, so clear on the Schuylkill, cannot be recognized much further southwestward. Indeed, the typical Manayunk rocks so prominent on the Schuylkill are scarcely to be found three miles west of it.

Near the mouth of a small creek flowing into the Schuylkill near Strawberry Mansion, Fairmount Park, is a rock apparently identical with one found by Dr. George H. Williams and described by him as follows: "In specimens collected on Sligo Branch;[146] the surface of this rock was covered with small nodules, which upon examination proved to be made up almost entirely of quartz and sillimanite, a mineral combination strongly suggestive of the contact metamorphism of included fragments."[147]

In an excavation in the mica schist made for water-pipe near the Queen Lane reservoir, in Germantown, Philadelphia, two masses of quartz were observed looking like elongated pebbles. They are oval in section, one measuring 5 x 3 x 10 in., but one end was broken off. The original length was probably a foot; the other was much larger. They are composed of a hornstone-like quartz, jointed so that they fell to pieces on extraction, the joints thinly coated with probably hyaline quartz with dendrites. They were imbedded in a very soft mica schist.

Before discussing the rocks of western Delaware county and southern Chester county, it will be well to consider the topography and drainage systems of the region.

The Schuylkill flowing with a nearly south course across the Chester Valley limestone and the hydromica schist strikes the ancient gneiss hill, and for a mile and a half flows along its base a little north of east. Then, breaking through by a steep-sided gap, it flows with a nearly straight southeast course until the porphyritic gneiss is reached at the Falls. This hard rock does not divert it, but immediately after crossing the gneiss the river flows

[146] Probably Fairfax county, Va.
[147] *U. S. Geol. Survey,* Fifteenth Ann. Rep., p. 665.

nearly south for a mile and a half through schists and gneisses of varying texture and hardness to Columbia Bridge. Here on the left bank is very hard hornblende gneiss (altered diorite?), with some pegmatite; this again does not divert it, but immediately after, it takes a southeast course until it has passed Fairmount, then southerly, with curves, to its mouth. Southeast of Buck Ridge its drainage area on its right bank is very limited for so large a stream, not exceeding four miles in width at any point, and being as narrow as one and a half miles.

Darby creek and its branches drain the next area to the southeastward between nearly southeast parallel lines about six miles apart, the creek rising on the southerly edge of the hydromica schist and flowing through the ancient gneiss, here nearly three miles wide, and then through the schists. The stream bed is high and the erosion much less than at the Schuylkill.

Next is Crum, then Ridley creek. In their lower courses the drainage areas of these creeks are parallel to that of Darby creek and very narrow, the creeks themselves being but about two miles apart and their combined drainage areas not much over four miles wide. Their northwestern branches, however, spread out to the westward and along the northerly edge of the ancient gneiss and cover a lineal distance of six miles.

The next, Chester creek, is roughly parallel to Ridley creek, but its headwaters also spread out to the westward so that its general course is about east-southeast, while its west branch drains a large area to the southwest. The parallelism mentioned is not perfect, for all the streams converge, and all, except the Schuylkill, enter the Delaware within three miles. All these streams, except the Schuylkill, rise either in the ancient gneiss or along the base of the hydromica and are comparatively small, but owing to their rapid descent, suggestive of geologically modern origin, subject to sudden floods.

The next stream, the Brandywine, is second in importance to the Schuylkill. It rises in the Welsh Mountains in the extreme northwest corner of Chester county. It has two large and important branches. These rise close together and flow southeastwardly across the strike of the rocks and through deep valleys, one to six miles apart, for a distance of about eighteen miles to the southeast edge of the ancient gneiss, where the east branch turns southwest

and joins the west branch six miles from the Delaware State line, to which point its general bearing is a little east of south, but with a serpentine course.

By another important branch, Buck-and-Doe run, and its branches, Buck run and Doe run, the whole of central western Chester county is drained, leaving a comparatively small southern and southwestern area to be drained by nearly south flowing streams, Red Clay and White Clay creeks, except the extreme southwest by Big Elk creek.

The Octorara flowing along the west line of Chester county drains but a small area on its left bank.

Darby Creek Section.

The Darby creek section shows southeast of the ancient gneiss, the spangled schist, here gneissic and quite porphyritic, then the serpentine of the LaFayette belt, then Chestnut Hill schists with a preponderance of sandy schist and some hornblende schist, following which are plicated mica schists and gneisses, usually quite hard, and the porphyritic gneiss. Kyanite and staurolite occur near the Philadelphia city line and to the southeastward, but the Fairmount gneiss does not appear.

On this section, from the West Chester and Philadelphia road southeastward pegmatite is frequently found, but usually the contacts are concealed. On the above road, about .2 mile east of Darby creek, two sheets or veins of pegmatite occur, apparently conformable with the enclosing schists. They are almost wholly feldspar. The eastern dips N. 35° W. 40°, and is from eighteen inches to two feet wide. Three feet east of it, and apparently conformable, is a sheet of feldspar with much bluish quartz. Two hundred feet westward is a sheet of the pegmatite, dipping irregularly but gently to the northwest. In these beryl and tourmaline occur sparingly.

The section afforded by Crum creek presents new features. At Darby creek the ancient gneiss is over three miles wide; at Crum creek this area, which here is wider, is divided by a small valley heading in the gneiss on the Philadelphia and West Chester road one mile west of Newtown Square. Here there are obscure traces of schists, close to the well-known serpentine and enstatite of Castle Rock. The arm of ancient gneiss to the southeastward has

a width of one mile. The schists, serpentine and enstatite are probably not over 500 feet wide at the creek, if so much. On the southeastern edge of the gneiss are outcrops of serpentine, not immediately on the creek, but to the northeast (Blue Hill). South of Walter Green's the Chestnut Hill schists seem to end in a point, and more compact and heavily bedded schists and gneisses to take their place. In these occur a line of serpentine outcrops, but whereas at Walter Green's and Blue Hill serpentine proper is in very great excess, in these it is subordinate, the chief rock being impure talc schist and antholite (?), the latter being quarried for use as asbestos.

Southeast of this is a wide area of the schists, mostly hard and micaceous but embracing some outcrops of hornblende schist.

On the Media Railroad, southwest of Swarthmore College, but east of Crum creek, is a rock consisting almost wholly of hornblende and very slightly schistose, which is probably an altered diorite. A similar rock was found in the tunnel of the Baltimore & Ohio Railroad west of Darby creek.

The same hornblende rock can be traced nearly north and south from the outcrop at Swarthmore, the most southern outcrop being on the right bank of the creek about a quarter of a mile south of the bridge at Avondale.

On the left bank of the creek, just below the Media Railroad bridge near Swarthmore College, and just east of the hornblende, the mica schists are exposed in great masses, some of which contain andalusite (sillimanite ?) in imperfect crystals, perhaps due to contact metamorphism. About a mile distant, in masses of quartz found loose in a wood, were remarkably perfect andalusite crystals, some doubly terminated. This mineral is reported also from Leiperville, a village on the Philadelphia and Chester road near Crum creek. I have a specimen so labeled, which came from an old collection and which differs decidedly from that from near Swarthmore, but I have been unable to learn the exact locality. Minerals from the Avondale quarries and from those on Ridley creek have been widely distributed labeled as from Leiperville, which is therefore a somewhat elastic term.

A mile below Swarthmore are large quarries in gneiss resembling that of Fairmount, but with the schistose structure more fully and regularly developed and with joints more regular and less numer-

ous, making a valuable building stone. The largest quarry is that of Leiper & Lewis, which has been wrought for over fifty years. Many thousand cubic yards of stone have been removed, much of which has been used in important structures. The excellence of the stone was recognized so early that one of the very first railroads built in the United States connects these quarries with tidewater a few miles below.

In these quarries pegmatite beds, veins or sheets occur, carrying many of the minerals occurring near Fairmount. Particularly fine beryls and garnets have been obtained.

Ridley Creek Section.

The section afforded by Ridley creek is so close to that of Crum, that it is very similar. Where Ridley creek crosses the schist valley in the ancient gneiss, the western branch flowing along this valley joins the main stream, which then follows the schist valley in an easterly direction for nearly a mile before resuming its southeasterly course. From this point west-southwestward the schist valley becomes more prominent and wider, with a very straight course. With but few interruptions it may be traced far into Chester county, its floor, occupied by the Street road, being composed of Cambrian sandstone and limestone with the schists.

Near the right bank of Ridley creek and northwest of the schist valley is the Willistown (Chester county) serpentine, almost certainly a continuation of that at Castle Rock.

Leaving the schist valley, here probably less than .2 mile wide, the creek flows for over two miles through the southerly branch of the ancient gneiss to Sycamore Mills, where the edge of the gneiss forms prominent and high hills on both sides of the creek, and serpentine appears.[148]

[148] It is but fair to say that Mr. Hall, in the map accompanying C^5, interprets this region very differently. Instead of a very narrow valley of schists beginning a mile west of Newtown Square and widening gradually to 500′ at Ridley creek, bounded north and south by the ancient gneiss, he continues the Bryn Mawr schists northwardly up Ithan creek and Darby creek to Camp run, showing more than a mile of schists north of the Roberts road at Darby creek and nearly as much north of the serpentine of Moro Phillips' chrome mine, thence westward, including Central Square and Newtown Square. Southwest of Newtown Square an area of the gneiss is shown rapidly widening westward and cutting off the schists on the right bank of Ridley Creek. At Castle Rock and thence east to Newtown Square the schists are represented as over a mile in width.

But in this area are hundreds of bold outcrops of the typical gneiss ex-

Southeast of the Sycamore Mills are the Blue Hill and Dismal run outcrops of the serpentine, the continuation of the Walter Green outcrop in Marple, then mica schists among which are scattered outcrops of enstatite, antholite, serpentine and a coarse binary granite, including the celebrated Mineral Hill. Much of this area is of the schists in which the serpentine rocks appear, accompanied by a granite or aplite, sometimes free from mica, and often composed almost entirely of oligoclase in crystals and crystalline masses as much as three inches in diameter, with a small percentage of quartz. This appears to be in dykes or sheets as if intrusive in the schists. Two localities in particular illustrate this, one at the easterly end of Crump's serpentine quarry, west of Media, where the granitoid rock had every appearance of a true dyke;[149] the other, on the left bank of Chrome run, three or four hundred feet above the railroad near Williamson Station, shows a mass of hornblende rock striking about northwest, while within two feet of it is the granitic rock striking nearly at right angles. An excavation here would be interesting.

Southeast of Media there are the same schists as on Crum creek. Approaching Chester we find the more feldspathic gneiss resembling that of Fairmount. Two of the largest quarries of the region lie on the left bank north of the Philadelphia and Chester road, Leiper's and Deshong's, but the best stone has been removed to a depth too great for profitable working. At the northwest end of Deshong's quarry is a fine exposure of pegmatite.

Chester Creek Section.

Chester creek rises on the southerly edge of the hydromica, flows southeasterly across the mica schists, the serpentine, and the ancient

actly like that elsewhere so represented—*e. g.*, on the Radnor and Chester road, all along Darby creek, a quarry on the right bank of the creek north of the Roberts road, the cut of the Philadelphia and Delaware County Railroad, about a tenth of a mile northwest of the serpentine and of Fawkes run; between Newtown and Central Square, dipping S. 30° E. 30° to 60° and S. 50° E. 65°; on the road from Newtown Square to Castle Rock, S. 25° E. 75° at the forks and S. 20°, E. 60° close north of the serpentine east of Castle Rock. My view is, as elsewhere expressed, that west of Newtown Square the ancient gneiss tableland is divided by a narrow valley of the schists, the southerly portion narrowing rapidly and ending east of Chester creek, while Mr. Hall continues it south-southwest, making it unite with and include the gabbro area of Chichester and Lower Chichester.

[149] The quarry has been abandoned many years and the falling in of the sides has nearly obliterated this.

gneiss, and enters the mica schist valley spoken of close to Westtown school, near which the valley can be well seen and the hills of ancient gneiss bounding it. Southwest of Westtown school the southerly arm of ancient gneiss ends, and schists and schistose gneisses only are found. Many of these, however, are of a decidedly harder character than most of those along Ridley creek and to the northeast. They do not, however, differ from the harder strata of the northeasterly gneisses, and in places between the two creeks, as along the railroad west of Media, the hard gneiss may be seen in narrow layers between the strata of soft mica schists. They do, however, differ most markedly from the much harder and little schistose rocks of the ancient gneiss to the north and east.[150]

In the north the best exposures are afforded by the West Chester (*via* Media) branch of the Pennsylvania Railroad, which from West Chester follows the west branch of Chester creek and then the main stream to Wawa. The ancient gneiss can be recognized clearly for some distance beyond the two-mile post from West Chester. About .1 mile beyond it the gneiss dips N. 25° W. 10°, and 150 feet further N. 30° W. 15°. This is about .15 mile west-northwest of Oakbourne Station. The cut just above the station shows a feldspathic gneiss much decomposed, dipping N. 50° W. 60°. Below the station is a feldspathic gneiss, dipping about N. W. 45°, and 100 feet beyond a similar rock, more decomposed, with plicated beds, dipping N. 45° W. 70°. This is about 100 feet north-northwest of the three-mile post. One-tenth mile beyond the post is a cut in a feldspathic gneiss, weathering almost black upon the surface, somewhat schistose, dipping S. 55° E. 50°, and about .1 mile further a small quarry in similar but more micaceous gneiss, showing a small distinct anticlinal N. 30° W. 55°, S. 60° E. 50°, with a downward pitch to the northeast. The border between the ancient and newer gneiss I believe to be somewhere near the three-mile post. The slopes are much more gentle until Chency Station is reached; this being the floor of the schist valley referred

[150] Mr. Hall, however, regards them as the same as the ancient gneiss and as occupying very irregular areas in Concord, Middletown, Aston, Bethel and Upper and Lower Chichester; but, according to my observations, except in portions of the last three townships, the rocks are identical in the areas differently colored and are very unlike those in the area to the north colored for Laurentian. Into Bethel and Upper and Lower Chichester and probably further the gabbro area of Delaware extends (F. D. Chester, *Bul. of the U. S. Geol. Survey*, No. 59).

to as heading west of Newtown Square, the Street road crossing the creek at Westtown Station about half-way between Oakbourne and Cheney. Six-tenths mile above Cheney on the right bank of the creek the schists are exposed. At Cheney the hill bounding the Street road valley on the southeast crosses the creek, as does also the very irregular county line (Delaware-Chester). The rocks exposed seem to be almost exclusively large loose masses of a hard gneiss, mostly hornblendic. They do not resemble those of the ancient gneiss to the north, nor those of the same (topographic) hill to the northeast. Blue quartz is absent, the boulder decomposition likewise. They do resemble the hornblende rocks of Columbia Bridge, Swarthmore, Darby, etc., and are not improbably altered diorites. About .5 mile below Cheney and above Locksley Station is a small cut showing a feature exhibited also to the westward near Concord Station (Baltimore Central Railroad) on the west branch of Chester creek. This is a decomposing rock, weathering alternately into laminated very soft schistose layers one inch to eight inches wide, and layers of small, hard, angular blocks of very hard rock one inch to four inches wide. Of the latter sixteen were observed in a space of eight feet. The schistose portion appears to have been a schistose gneiss; the harder masses, the interior of which appears to be undecomposed, were examined for me by Mr. Goldsmith, who classed it as a diorite. Dr. Bascom classes it as a gneissoid gabbro diorite. Northwest of Concord Station the same alteration is visible, but on a larger scale. The hard rock here was determined by Dr. Bascom to be a gabbro diorite. One dyke (?) of it is about four feet in width. The intermediate strata have all the appearance of decomposed gneiss and mica schist. Near the west branch of Chester creek, about a mile nearly north of Concordville, Dr. Charles Schäffer discovered a single large mass of a gneissoid gabbro with a reticulated structure. It consisted of feldspar, quartz and garnet, arranged in narrow straight veins (?) often several inches long, some parallel, others crossing it at various angles, and often several in an inch with no general parallelism. In the triangles and rhomboids thus formed is a black rock, chiefly hornblende and garnet. A short distance above Locksley Station is a gneiss S. 80° E. 50°, then a highly ferruginous rock, followed by a stratum resembling trap and a gneiss, weathering black, S. 60° E. ± 10°. About .1 mile below Locksley is a large quarry in

a garnetiferous gneiss, dipping 30° to 70° S.E. In the railroad cut just below, the same gneiss dips 0° to 20° S.E.

Above Glen Mills similar rocks, but rather more micaceous, are exposed with southeast dips of 20° to 30°. Below Glen Mills is a large quarry in similar rock, dipping S.E. ± 70°, and another near Wawa.

Near Glen Mills are outcrops of serpentine on the right bank, and also about three-quarters of a mile northeast; adjoining the latter is a considerable outcrop of coarse pegmatite (Sharpless' quarry) which has been quarried for its feldspar and mica.

Below Wawa and near Lenni on the left bank are extensive outcrops of serpentine with much coarse feldspar rock, probably oligoclase, containing very little quartz, and almost no mica or hornblende, being evidently the continuation of the similar rocks west of Media.

Schists and gneisses not essentially different from those above continue down the creek, but in many places they are deeply decayed. In these decayed schists amethysts are found, some of much beauty, also a quartzite filled with small crystals of tourmaline. Near Morgan's Station (Dutton's mill), Dr. J. T. M. Cardeza found a loose mass, apparently a sandstone, containing elongated quartz pebbles. This was near the amethyst and tourmaline localities.

On the right bank, near Morgan Station, mica schist with alternations of hornblende schist dips S. 20° W. 70°. Here, in pegmatite, Mr. Glanding Dailey recently discovered the rare mineral monazite, its only known occurrence in the region. A little to the westward was found, loose in the soil, very small but brilliant transparent ruby-red crystals of rutile on colorless quartz crystals.

On the left bank, near Bridgewater Station, is a large quarry in rock resembling that of Lenni and Glen Riddle, but containing more mica, with dips S. 60° W. 60° to 90°, S. 65° W. 65°, while on the right bank a coarse pegmatite has been quarried for its feldspar and mica. Near Upland a feldspathic gneiss was quarried, and also between it and Chester. The beds of gneiss of the Avondale quarries and of Deshong's and Leiper's, on Ridley creek, do not appear on Chester creek. The ground is lower and they are probably covered.

Between the main stream of Chester creek and the Brandywine is a region of high ground with few good exposures, but some points

of interest. In the longitude of West Chester the northerly branch of the ancient gneiss narrows rapidly and in Westtown and East Bradford townships, its southern border appears to describe approximately an arc of about two miles radius with a centre near the railroad station in West Chester, serpentine outcrops being not far from the margin. The Street road valley continues, but not so distinctly as to the eastward. In it we find the Cambrian sandstone and limestone, apparently the outliers of the large areas west of the Brandywine. The easternmost exposure of the sandstone is in the road running southwardly from Oakbourne Station, about a quarter of a mile south of the Street road, on the farm of John Wyeth.

The exposure is poor, but the rock unmistakable and clearly in place. Nearly a mile to the westward the Wilmington road crosses the Street road. On the former sandy schists dip gently southeast for over a mile, and among them, about a half-mile north of Dilworthtown, the sandstone appears in quantity, but its outcrop in place is concealed. The schists north of it dip 15° to 0° S.E., south of it 15° to 30° S.E. The outcrop must be narrow. About a quarter of a mile west-southwest from this locality, on the farm of Minshall Sharpless, the sandstone is well exposed in a small quarry, the rock dipping N. 35° W. ± 80°. Southwest of this about .2 mile, on the road from Dilworthtown to Birmingham Meeting-house, and about .2 mile west-northwest of Dilworthtown, is a considerable outcrop near the forks of the road, fragments only being visible. Following the right-hand fork north-northwest about .7 mile a small limestone quarry with a dip S. 40° E. 50° is found on a branch of Radley run. This is near the western border of Thornbury township, about .6 mile south-southeast of Brinton's quarry and about a quarter of a mile nearly east of Birmingham Meeting-house. South of it are abundant schist fragments, with one outcrop in place S. 30° E. 30°, with abundant evidence of decomposed mica and hornblende schist. Inasmuch as along the Street road, the north line of Thornbury township, schists dip ± 15° S.E., it would appear probable that the structure is monoclinal.

The Brandywine section from the ancient gneiss at the forks three miles southwest of West Chester is as follows, the general course of the creek being about S. 30° E., or nearly on the line of the dip:

Distance.	*Dip.*	
0. miles.	S. 60° E. 45°.	*North of East Branch:* Ancient gneiss.
1. "	S. 15° E. 20°.	Schistose, porphyritic gneiss.
1. "	S. 40° E. 40°.	*Lenape:* Porphyritic with crystalline muscovite, and mica schist.
1.7 "	S. 60° E. 50°. N. 40° W. 20°. ± S.E. 90°. Prevailing dip S.E.	Hard feldspathic gneiss with considerable mica and a little mica schist, the gneiss schistose and porphyritic with waves and folds, but no minute plications.
2. "	S. 35° E. 55°.	*Street road:* Sandy mica schists not exposed at the creek, but to the eastward, and more largely to the westward, where they enclose Cambrian sandstone and limestone.
2.7 "	S. 30° E. 30°.	*Half a mile above Brinton's bridge:* Hard plicated gneiss and hornblende gneiss, gabbro and pyroxenite.
3.3 "	S. 25° E. 25°.	*Harvey's limestone quarry, N. W. wall:* Hard gneiss with mica schist.
	± S. E. ± 45°.	*Harvey's quarry:* Limestone.
	S. 20° E. 45°.	*Harvey's quarry, S.E. wall:* Hard gneiss.
4.1 "	S. 30° E. 30°.	Hard gneiss, left bank.
4.15 "	S. 10° E. 65°.	Schist and gneiss, some porphyritic.
4.2 "	S. 20° E. 70° to 90°.	Same, some coarse porphyritic with decomposing feldspathic micaceous rocks.
4.25 "	± S.E. ± 45°.	Gabbro (?), left bank.
4.3 "	S. 40° E. 45°.	Heavy-bedded feldspar and hornblende gneiss.
4.5 "	S. 20° E. 85°. S. 30° E. 70°. N. 30° W. 40°.	Hard plicated gneiss, left bank.
4.7 "	N. 30° W. 20°.	
4.6 "	S. 40° E. 45°.	Gneiss.
4.7 "		*Chadd's Ford Junction:* No good exposure. To the westward a marked valley with limestone and sandstone.

Distance.		*Dip.*		
4.8	miles.	S. 70° E.	70°.	Garnetiferous schist.
4.9	"	S. 55° E.	45°.	Very schistose gneiss.
5.	"	S. 60° E.	35°.	Schistose gneiss.
5.4	"	S.	70°.	Schistose gneiss.
		S. 20° E.	70°.	Schistose gneiss decomposed.
5.9	"	S. 40° E.	60°.	Mica schist and gneiss.
5.9	"	S. 30° E.	50°.	Hard hornblende schist and mica schist. Altered gabbro (?).
6.1	"			*Brookfield Station:* Like the last, but with included masses of feldspar.
6.5	"	S. 10° E.	70°. 80°.	Hard mica schist. Loose masses of quartz and mica as if decomposed pegmatite.
6.6	"			*Cossart Station.*
7.	"			Delaware line.[151]
7.5	"	S. 50° E.	50°.	Very hard, heavy-bedded mica schist.
8.7	"			*Granogue Station.*
9.4	"	N. 50° W.	50°.	Mica schist and gneiss in the middle of a cut, hornblende schist at both ends. The schist and gneiss contain red garnets.
9.2	"	N°. 40 W.	80°.	Hard heavy-bedded hornblende schist and mica schist.
10.6	"			*Guyancourt Station.*
10.7	"			Mica schist gneiss and pegmatite.
11.1	"			Thin-bedded mica schist.
11.2	"	N.	40°.	Hard mica schist and gneiss.
11.5	"			*Winterthur Station.*
11.6	"			Hard mica schist and gneiss with a little pegmatite.
12.5	"			Gabbro.

Below Chadd's Ford the curvatures of the creek are so numerous and great that the distances on the dip line are probably not seventy-five per cent. of those given, and between Winterthur and Cossart not much over fifty per cent.

The Schists and Gneisses West of the Brandywine.

This region is mostly high, the slopes not rugged except toward the Brandywine, and usually decomposition has altered the surface

[151] Between Cossart and Granogue the creek and the railroad bend in the form of the letter S and cross the State line three times.

rocks to a considerable depth. On the northern margin near the ancient gneiss and also at a few scattered and insignificant outcrops further south serpentine appears. In the midst and to the south the Cambrian sandstone, with adjacent limestone, forms lines of outcrop; two being about seven miles in length. Almost invariably the dips are to the southeast, and not steep.

While the principal streams flow from north to south, there are three east-and-west valleys. Of these the southerly two are limestone valleys, and of these the northerly is the continuation of the valley mentioned as heading near Newtown Square and followed by the Street road, a valley of limestone with adjacent sandstone, the bounding hills being of schist and gneiss. The southerly is a similar valley, occupied by the Baltimore Central Railroad. The northernmost of the three is that occupied by Pocopsin creek. Like the others it is very straight, but limestone occurs at but one insignificant locality, a quarter of a mile north of the axis of the valley.

South of Northbrook a section through about the middle of Pocopsin township, nearly on the east line of East Marlborough, and through the middle of Kennett would show, south of the ancient gneiss, here not over .4 mile wide: (1) serpentine (Pocopsin Inn); (2) mica schists with gentle southeast dips, some loose masses of talc schist, sufficiently abundant to indicate an outcrop, and limestone (the talc and limestone on the Larkin farm, about .5 mile south-southeast of Pocopsin Inn); (3) mica schist, abundant in loose masses but without measurable outcrops; (4) serpentine (one mile nearly south of Pocopsin Inn); (5) the valley of Pocopsin creek, on which, nearly a mile to the eastward, mica schists dip S. 20° E. 40°; (6) a mile without exposures except of soil derived apparently from mica schist; (7) garnetiferous mica schists dipping S. 30° E. 40° on the Doe run road, .6 mile west-northwest of the Red Lion Inn, followed closely by decomposed sandy schists, and these by (8) the typical Cambrian sandstone, dipping S. 25° E. 15° to S. 28° E. 50°, with sandy mica schists immediately underlying, dipping S. 20° E. 25° (this sandstone to the westward borders the Street road limestone on the north). A mile to the south is the northerly line of Kennett township, and in this distance soil only was found. A quarter of a mile south of the line, at Marshall's, now Still's mill, on the

east branch of the east branch of Red Clay creek; (9) a very hard hornblende rock of trap-like aspect, dips (?) S. 25° E. 55°. This may be traced a mile or more to the eastward, and is probably an altered diorite. Associated with it are masses of pegmatite. The exposures of the latter are but of fragments. South of the gneiss is (10) a decomposed gneiss, with much rusty quartz, and south of it (11) Cambrian sandstone with quartzite and very sandy micaceous rock, dipping S. to S. 10° W. 30°. This is just south of Red Clay creek, where it turns from a nearly south to a west-southwest direction, and about .3 mile east-northeast of the limestone of the Sharpless quarry. South of the sandstone are (12) decomposed hornblende and feldspar gneisses, dipping apparently nearly 0°, with few exposures. The most prominent rock is a very hard, tough hornblende gneiss, usually visible in large loose masses only, but largely exposed in place on the east branch of Red Clay creek at Pierce's paper mill, a little west of this section line, about .75 mile southeast of Kennett Square Station. At this point a single specimen of cancrinite, now in the collection of the Academy of Natural Sciences, was found many years ago by Mr. Jefferis and Dr. Isaac Lea. So far as can be observed this hornblende rock appears in narrow outcrops which cannot be ranged in a single line, though a nearly east-and-west line will pass through several of them.

These rocks suggest an altered diorite. They contain plagioclastic feldspar, sometimes finely aventurine, also titanite and chabazite. While this gneiss appears to be the most prominent rock, it is probably in very much less quantity than a more feldspathic gneiss, subject to more speedy decomposition.

This hard gneiss, another outcrop further south, and that at Still's mill were regarded by Prof. Rogers as rising in anticlinals through the schists,[152] by Dr. Frazer as a gneiss older than the schists,[153] and by Prof. Lesley as three separated areas of the old azoic gneiss.[154]

Similar rocks can, however, be traced among the mica schists into the great gabbro area of Delaware so well described by Prof. Chester, who cites one locality on the Brandywine just below

[152] I, p. 77.
[153] C^1, 315, 316.
[154] *Final Report*, I, p. 79.

Jessup & Moore's paper mill at which foliated hornblende rock, much resembling that of Kennett, may be seen between "perfectly massive gabbro without the least sign of any distinct line of separation between the two structurally different rocks."[155]

This is certainly a most interesting locality, confirming very positively the views of Mr. Chester, who, I believe, was among the first to urge a plutonic origin for these rocks,[156] though Prof. Lewis still more forcibly published the same views, extending them to other less massive rocks.[157]

A section about three miles west of the last, or nearly north and south of Embreeville, shows the absence of the ancient gneiss, which has ended west of Northbrook, and hence a great width of the schists and gneisses, from the hydromica on the north to and beyond the Delaware line, a distance of some eleven miles. To the northward we find hydromica schist, cut by the Downingtown trap dyke, near the headwaters of Broad Run, West Bradford township. A half-mile south of Cottage schoolhouse, and .75 mile north of Romansville, these schists, dipping S. 70° E. 70°, form a high bluff. This seems to be near their southern limit, which is characterized by a high ridge extending east-northeast toward the Brandywine. South of the ridge is a prominent valley, perhaps indicating the margin. This valley, somewhat interrupted it is true, may be followed from Romansville to Hawley's mill on the Brandywine, where, as already stated, the two series may be seen close together with diverse dips. In this valley there is a very small outcrop of dolomite, colored green by talc or chlorite, on the farm of Young's estate, .75 mile west of the Brandywine.

On Broad run, a quarter of a mile south of this valley, the hard spangled schists appear prominently, dipping about S. 15°. A half-mile south of this, on the Strasburg road, are soft mica schists, with some very feldspathic schistose gneisses, nearly vertical. About a quarter of a mile south of this we reach the line of limestone outcrops already referred to, extending from Cope's quarry, east of the East Branch, to Embreeville, on the West Branch of the Brandywine, and probably to Doe run. These, as

[155] F. D. Chester, *Bull. U. S. Geol. Survey*, No. 59, p. 43.
[156] *Proc. Acad. Nat. Sci.*, 1884, p. 248.
[157] H. C. Lewis, *Proc. British Asso.* in *Nature*, October 8, 1885, p. 560.

elsewhere more fully stated, seem to be overlaid and underlaid by schists and gneisses, in which is the typical Cambrian sandstone (Hayes' quarry, one mile west of the Poorhouse quarry). About an eighth of a mile north of the Poorhouse quarry, decomposing schistose gneisses dip S. 40° E. 45°, hence under the limestone. The schists over the limestone are from very nearly 0°, perhaps 5° S.E., to S. 50° E. 15°. South of the quarry are plicated schistose rocks containing feldspar and mica porphyritically enclosed. The dips vary from 0° to probably 40° S.E., while one clear dip near Glen Hall bridge had the unusual direction of N. 70° W. 10° to 40°. One mile southeast of the Poorhouse quarry and .5 mile east-northeast of Glen Hall is an outcrop of steatite and serpentine on the Lamborn farm, just north of a ridge of garnetiferous schist, the latter dipping S. 30° E. 20° to 30°. The localities south of the Poorhouse, also Hayes' quarry, are in Newlin township, the latter very close to the West Bradford line. Between the Poorhouse quarry and Embreeville is a low plain about .75 mile by 1.5 miles. It is not improbable that the existence of this plain is due to the limestone.

While at the Poorhouse quarry the immediately underlying schists are concealed, at Embreeville they are well and clearly exposed by a cut of the Wilmington & Northern Railroad, not over a hundred yards north of the limestone quarry. They are spangled and garnetiferous schists, dipping quite regularly S. 50° to 55° E. 30° to 45°. At the west end of the cut is a quarry in a decomposing, very white feldspar, the relation of which to the schists is not clear. So far as it appears it is a conformable stratum under or in the garnetiferous schists.

The feldspar has been mined for use in the making of pottery. It is a "soda orthoclase, with a slight admixture of lime feldspar and considerable free quartz."[158]

The limestone dips in nearly the same direction as the schists, S. 45° to 50° E. 60°. About a hundred yards southeast of the limestone, schists and gneisses with one granitoid stratum, with tourmaline, dip S. 50° E. 55°. South of this are hills of hard mica schists, dipping about 45° S.E., rising probably 250 feet above

[158] Prof. Thomas C. Hopkins, "Feldspars and Kaolins of Eastern Pennsylvania," *Journal of the Franklin Institute*, Vol. CXLVIII, p. 13, July, 1899.

the Brandywine, and exposing, a little north of the summit, much white and much rusty quartz. The white quartz contains small crystals of back tourmaline, and seems to form a distinct stratum, striking about N. 20° E., observable, however, only in loose masses on the surface.

The summit of the hill and its eastern slope show fragments of mica schist only, with much quartz, the surface of which is stained yellow.

About one mile to the eastward of this hill is the extensive outcrop of enstatite serpentine, coarse pegmatite and trap, the well-known Newlin corundum locality, noted for its diaspore, beryl, tourmaline and other minerals besides the corundum. This is less than half a mile from the apparent western ending of the ancient gneiss. The schists close to the ancient gneiss appear to dip away from it. Thus .2 mile west of Northbrook N. 70° W. 67°, N. 20° W. 25, a little further south nearly W. ± 45°, a half-mile further south ± W. ± 30°. A half-mile to the west of the last the southeast dip seems to be resumed.

A mile and a quarter south of Embreeville the north line of East Marlborough is crossed, and mica schist and coarse pegmatite occur poorly exposed. Then follows a half-mile of schist soil, with much loose quartz, but no rock in place, until the Doe run road is reached.

On the Doe run road, west of Unionville, the soil is of decomposed schist. About a half-mile west, a narrow belt of hard gneiss, with spangled schist, crosses the road. The hard gneiss is only about ten feet wide; its strike is N. 20° E., dip 90°. The spangled schist a little east of it dips 15° S.W. A half-mile further west the road passes through a cut of garnetiferous mica schists, dipping S. 30° to 50° E. 40° to 60°, just beyond which and to the northward is Logan's limestone quarry, the limestone dipping S. 40° to 45° E. 40° to 50° under the garnetiferous schists. A little over a hundred yards west of the limestone is an outcrop of the sandstone dipping S. 75° E. 30°.

South of the Unionville-Doe run road, exposures were not found, but one mile southeast there is a quarry on Milton Thornbury's farm at the head of the east branch of Red Clay creek, showing a micaceous gneiss S. 60° E. 15°, with a vein of quartz dipping S. 85° W. 70°.

Three-quarters of a mile south of this quarry is the Street road, which here, according to Breou's map, runs S. 85° W. parallel to the south line of East Marlborough township; on this road sandy mica schists, with typical Cambrian sandstone, dipping S. 5 E. 15° to 20°, may be seen. South of this is the Street road limestone belt. At Taylor's quarry, about a mile and a quarter west-southwest of Taggart's cross-roads (Willowdale Post-office), the contact of the limestone with overlying mica schists (locally known as firestone and used for lining limekilns), is well shown. The mica schist dips S. 30° E. 20°, the limestone about the same or more gently. In Pusey's north quarry, which is about a thousand feet S. 50° W. from Taylor's, the same schists appear to the southeast, and to the northwest mica schist, dipping N. 35° W. 70°. In the northeast corner the limestone dips N. 25° W. 15°, while on the south side it is S. 25° E. 50°, a clear anticlinal, if these dips may be trusted, but the plications in the limestones of this region are so numerous that they probably cannot. The rocks immediately adjacent to the limestone on the northeast and southwest are not alike.

About 500 feet southeast of the Taylor quarry, mica schist and gneiss dip S. 50° E. 50° with plications, and about a mile south-southeast on Red Clay creek, close to the north line of Kennett township, there is a quarry on the left bank in a very hard close-grained mica schist, S. 50° E. 45°, while just below on the right bank is one in a hard biotite gneiss S. 40°. South of this is the mica schist hill on which the village of Kennett Square stands, known to the westward as the Toughkenamon hill. This seems to be chiefly of mica schist, some highly micaceous, some very sandy and approaching closely the typical Cambrian sandstone, some quite garnetiferous. The sandy varieties are best shown on the road running north from Kennett, also north of the State road and on the latter close to the west branch of Red Clay creek, .75 mile west of Kennett Square, and on the left bank of the creek, west of the State road (the main street of Kennett Square).

Kennett Square Station is at the southern edge of the village, and about ninety feet below the State road. The railroad occupies the valley in which limestone occurs, both to the east and to the west. South of this is the hard, rather coarse hornblende gneiss before spoken of, well exposed at Pierce's paper mill, .75 mile southeast of the station, as stated in the preceding section.

South of these hard gneisses the schists occupy most of the area, and near the Delaware border there is another line of limestone outcrops which extends from Jackson's quarry, Hockessin, Delaware, through Brown's quarry to the Nevins' quarries, with schistose and garnetiferous gneiss certainly overlying and apparently underlying the limestone.

South of the Nevins' quarries are mica schists, poorly exposed, covering a large area in northwestern Delaware. In these, between two and three miles south of the line of the Nevins' quarries and the Brown quarry, are the Eastburn limestone quarries, apparently with schists above and below the limestone, and perhaps interstratified, as the three quarries with southeast dips are apparently separated by schists and lie in a northwest-southeast line. The south quarry shows plications, but a general southeast dip. One satisfactory measurement was S. 40° E. 25°, but the northwest side of the quarry is a wall of mica schists dipping N. 65° W. 65°, but not over 200 feet northwest of this is the second, and probably largest, quarry; no rock showing but the limestone dipping S. 40° to 50° E. 20°.

Before discussing the next section it may be expedient to trace to the westward the northern edge of the mica schists, which was previously traced from the Schuylkill to Broad run one mile north of Romansville, West Bradford township, Chester county. About three miles to the westward, on the West Branch of the Brandywine, the northerly border of the mica schists is well defined, the creek itself seeming to flow nearly on the line east of Modena, the hydromica schist on the left or north bank dipping nearly south about 45°, while the hard mica schists on the right bank dip quite irregularly S. 80° W. 30°, S. 20° E. 50°, S. 10° W. 20°, S. 40° W. 20°, S. 35° W. 30°. On the right bank of the creek .2 mile north of Mortonville a quarry has been opened in a hard mica schist, in which the quartz grains are elongated. West of this the Strasburg road seems to be in the mica schists to a point northeast of Ercildoun.

Buck run affords excellent exposures. The hydromica appears about .25 mile northwest of Newlin Station dipping S. 50° E. 80°, while .15 mile above the station the mica schists dip S. 25° to 50° E. 20° to 45°. West of this the hydromica schists extend along the Highland road, while a mile to the south of that road the

mica schists form low cliffs on the left (northwest) bank of Fawn run, south of Harmony schoolhouse.

In West Fallowfield township the line is between Cochranville and Hudson's grist mill on Officer's run, near the Gap and Newport turnpike, and on the Octorara in the vicinity of Steeleville.

Through East Fallowfield, Highland and West Fallowfield townships, the mica schists adjoining the hydromica, where not decomposed, are heavy-bedded, largely of the spangled or conchoidal variety, dipping usually to the southeast less than 50°, best shown along the West Branch of the Brandywine, where they form some high and steep cliffs.

South of this border of hard rocks are more quartzose and sandy schists often containing garnets, from which the harder schists are nearly free.

A section about four miles west of Embreeville, that is nearly south of Coatesville, passing through East Fallowfield, West Marlborough, London Grove, Franklin and London Britain, and the valleys of Buck run, Doe run and the east branch of White Clay creek, shows many alternations of the schists and gneisses. To the north is the hydromica schist; following it, well exposed on Fawn run and Buck run, are the heavy-bedded mica schists with irregular dips and then the Doe run valley.

In West Bradford, Newlin and East Fallowfield are outcrops of the only distinct chlorite schist I have observed in Chester county. Except its intense green color it resembles the more evenly bedded mica schists, but can be quarried in flat slabs or flagstones used chiefly for paving walks, etc. The best-known outcrop is Fulton's quarry on the Speakman farm in Newlin township, about .4 mile north of Harvey's bridge on the Brandywine, and about .6 mile nearly west of the Hayes sandstone quarry. It also outcrops on the Strasburg road about a quarter of a mile east-northeast of Mortonville, and also on the road from Mortonville to Doe run. It dips S. 30° E. 20° at Fulton's quarry and appears to be the same at the other outcrops, though less favorable for measurement. Mr. Walter J. Baldwin informs me that it occurs in West Bradford a little over a half-mile southeast of Romansville, and also south-southwest, the former its easternmost exposure, the latter on the farm of R. M. Jefferis, where it has been quarried, and that there is another quarry, Young's, in Newlin township a little west of

Fulton's. Its margins are concealed, so that no exact measurement was possible, but apparently it is not a hundred feet thick.

The Doe run region differs markedly from the rest of the area, though the high hill seems to be of the same gneisses and schists. It was considered more fully when discussing the limestones. One view of it is that its limestones are the continuation of the Cope-Guest line merely interrupted for a very short distance by an anticlinal of sandstone and schists, that the schists which overlie the limestone overspread the whole area west of Doe run. The former is probably the fact, the latter more doubtful as some of the rocks underlying the limestones may be traced into this western area in which no limestone has been discovered. It is certain, however, that hydromica schists like those which bound the Chester Valley on the south do not overspread the area as represented on the map in C⁴, and in the text, page 105, *et seq.*

This western area requires further and careful study. I have not examined it as closely as the more easterly part, but so far as observed the rocks are mica schists, often garnetiferous with but little gneiss, and no hydromica schist such as forms the northerly part of the South Valley hill. The rocks are much decomposed, good exposures being few and far between, and even outcrops comparatively rare.

A few may be mentioned: East of Gum Tree, Highland township, mica schist and garnetiferous mica schist, N. 55° W. 55°.

East of Rosenvick, in the same township, mica schist with staurolite; a dip opposite Michael McLoughlin's is N. 60° W. 20°.

On the line between Penn and Londonderry townships, north of Townsend's mill, hornblende schist poorly exposed.

On the middle branch of White Clay creek, south of Townsend's mill, a very dark mica schist.

On the road to Oxford, about a mile and a half west of Jennerville, Penn township, a cut in garnetiferous mica schist, S. 65° E. 45°.

In Upper Oxford township, on the same road near Lincoln University, a cut in mica schist near a branch of Big Elk creek.

In Lower Oxford township, a half-mile north a little west of Elk View Station, on a mill race, very hard garnetiferous mica schist; dip uncertain.

Near the headwaters of the west branch of Doe run, near the

northwest corner of Londonderry township, on the farm of Susan Cochran is a rock differing from any other of the region. It is a very quartzose biotite schist, the layers being very well defined and often twenty or thirty to the inch, and these layers excessively plicated. Across these layers are mica partings dividing the rock into masses with roughly parallel sides. There appears to be but a single outcrop covering perhaps a quarter of an acre.

South of the Doe run valley is a hill traversed east and west by the State road. Mica schist with much loose quartz seems to be the only rock. Three-quarters of a mile south is the Street road. Along this mica schists dipping 30° to 45° S. 30° to 40° W. are exposed with trap, while both east and west of the southwest dips are southeast dips. A little west of Cook's grist mill a schistose gneiss dips S. 30° E. 50°, and near by a very sandy schist about S. ± 40° E. 15°. This is about a half-mile north of Chatham. At Chatham we reach the westerly extension of the London Grove outcrop of Cambrian sandstone, dipping S. 25° E. 55°. South of this no exposures were seen except at the limestone quarries ranging through the central part of London Grove township. The schist outcrops are so associated with those of limestone that they have been discussed with them. In brief, there are rather high hills of garnetiferous schists, with pegmatite and sandstone, all dips being southeast and gentle, some of the schists being apparently below the limestone and some very clearly above it. Similar rocks and gneisses continue to the Delaware gabbro area, being hard and forming bold bluffs near Landenberg, and surrounding, or at least on both north and south sides of, another limestone area. Usually these are not well exposed, but along Red Clay creek they form precipitous banks resembling those near Landenberg, dipping quite regularly S. 60°–70° E. 60°–70°, the rocks being undecomposed and hard, but to the westward they are decomposed and soft.

V. The Schists and Gneisses Lying between the Sandstone of the North Valley Hill and the Limestone.

These have been so referred to in discussing the adjacent rocks that they require little more than mention here. The fact then is that we have, between the well-marked Cambrian of the North Valley Hill and the limestone, sandy mica schists, rarely carrying feldspar and tourmaline, indistinguishable in their appearance and

lithological characteristics from some of the schists of the Philadephia and Manayunk groups; especially do they resemble the sandy schists of the Chestnut Hill group, and those on the Schuylkill below Laurel Hill, and in the cuts of the Schuylkill Valley Railroad southeast of West Laurel Hill.

VI. The Schists and Gneisses North of the Sandstone.

At Valley Forge, northwest of the sandstone, as has been stated, are slaty and schistose rocks, northwest of which is a conglomerate of blue quartz pebbles, resembling very closely the lower Cambrian conglomerate so well exposed near Willow Grove and to the southwestward.

Only six miles to the westward is the Pickering creek gap. We find here the easternmost of a series of outcrops of hard, usually schistose gneisses which prevail thence westward far into Lancaster county, bounded northwestward, in their easterly part, by the northerly ancient gneiss, and their westerly by the hill of Cambrian sandstone which stretches from west of the Gap in Lancaster county to Wagontown, Chester county. These vary much in their constitution as shown in Williams' quarry near Aldham, Charlestown township, where they dip S. 50° to 60° E. 60° to 65°, and in the adjacent railroad cut S. 80° E. 23° with great regularity and are cut by a dyke eighty feet wide of trap. This gneiss is very evenly bedded. It is sometimes hornblendic and sometimes highly feldspathic, indeed almost entirely a white feldspar; sometimes the feldspar is flesh-colored. This feldspathic variety contains small quantities of epidote.

I have termed it provisionally the Chester county gneiss.

Westward similar rocks are shown in all the gaps in the hill. Some of the feldspathic varieties have weathered into kaolin, but as a rule they are hard and undecomposed. A common variety to the westward resembles a pegmatite but has a brecciated aspect; beds of vitreous quartz occur and are quarried. It appears to widen westward and to occupy much of the space between the sandstone of the North Valley Hill and that of Copper Mine Ridge in western Chester and eastern Lancaster counties.

The Serpentines.

As to none of the rocks of this region has there been a greater diversity of opinion than as to the serpentines, including in these

the magnesian silicates, usually hydrous, of which serpentine is the type. Mr. Hall, after very careful study in Philadelphia, Montgomery and Delaware counties, concluded that all the serpentines of the region were of the same geological horizon, and that one of the most recent.[159] Dr. Frazer recognized the two different positions in which they occur, and states that the hypothesis that the serpentine is a layer of magnesian schist altered in place, while the most satisfactory in many respects, does not account for all that may be observed with regard to it.[160] Dr. Genth[161] showed that most of the serpentine was derived from the alteration of peridotite or bronzite.

Prof. Lesley thought them due, in part at least, to a metamorphism of the "talc mica" (hydromica) schist formation, due to the trap dyke which occasionally is close to the serpentine. My own views have already been published,[162] but in Prof. Lesley's *Final Report* (p. 107) are not correctly stated: "And this agrees pretty well with all Mr. Rand's observations of the serpentines of Delaware and Chester counties, which he shows pretty clearly to be interbedded among the ancient gneisses of that region."

It was my aim[163] to distinguish the hard, nearly black serpentines, derived chiefly from enstatite or bronzite, which I believe do occur either in or on the margin of the ancient gneiss, from those that are clearly in the mica schists and at some distance from the gneiss. These are usually of a lighter color, with less serpentine proper and with talc, steatite and antholite, which are rare in the former, and are probably altered peridotites in large part. The serpentine north of Easton, by far the best exposed of any in the region, appears at first sight to be interbedded in the ancient gneiss, though I am convinced that the theory of Dr. Frederick B. Peck,[164] that it is due to the alteration of igneous rocks, and per-

[159] C^5, pp. 13 and 14.

[160] C^4, p. 218.

[161] *Second Geol. Survey of Pa.*, B., I, pp. 62, 113; *Amer. Jour.*, Sec. (2), XXXIII, 199.

[162] *Second Geol. Survey of Pa.*, Assoc. Report, 1886, IV, p. 1611; *Proc. Acad. Nat. Sci. of Phila.*, 1896, p. 21, 1890, p. 76, *et seq.*

[163] *Second Geol. Survey of Pa.*, 1886, IV, p. 1611.

"If these steatite and serpentine belts" (the Philadelphia steatite and the LaFayette serpentine) "be compared, their unlikeness seems to point to a different origin . . . . . The serpentine belt has undoubtedly resulted from the alteration of enstatite."

[164] Private communication to the author.

haps also of adjacent gneiss along a zone of faulting and shearing, is in all probability the true one. I desire frankly to admit my mistake in regard to the supposed pseudomorphs after staurolite in the steatite quarry belt. The late Dr. Williams examined my specimens and identified them as pseudomorphs after olivine, and with this Dr. Bascom's observations of sections agree;[165] so that

FIG. 6. Serpentine after Olivine. Lafayette, Pa.

there seems no doubt that all the serpentines in southeast Pennsylvania are altered igneous rocks, either pyroxenites or peridotites. Fig. 6 is from a photograph by Dr. Schäffer of a specimen from Prince's soapstone quarry.

[165] *Proc. Acad. Nat Sci.*, Phila., 1896, p. 219.

Mr. Hall, after examining the *northerly* Radnor belt, modified his views, for he wrote (*Annual Report*, 1886, IV, p. 1617): "In all probability there are two groups of serpentines."

The change of pyroxenite into serpentine[166] is followed at many localities by the change of the serpentine into quartz, usually in cellular masses and sometimes in stalactites. Fig. 7 is of a specimen from the Philadelphia and West Chester road, a mile east of Newtown Square, photographed by Dr. Schäffer.

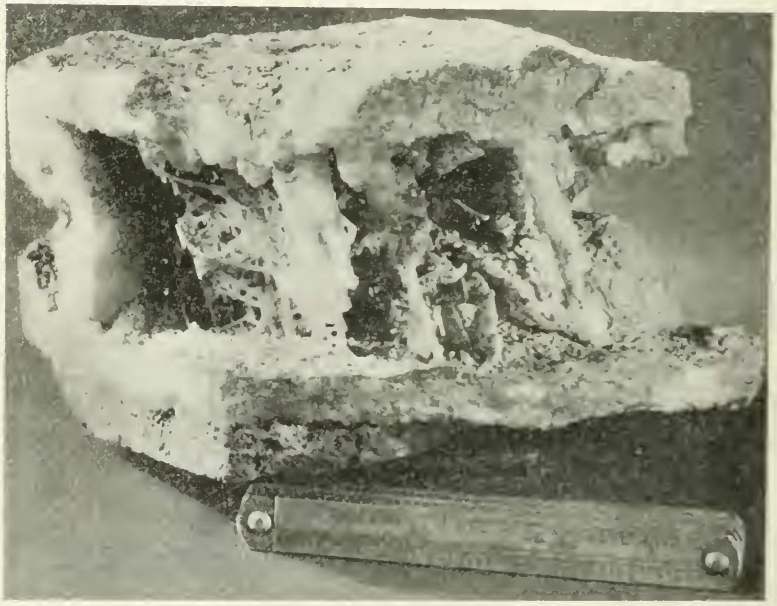

FIG. 7. Quartz after Serpentine. One mile east of Newtown Square.

To this recapitulation may be added some notes of observations made since those papers were written.

THE OUTCROPS IN CHESTER COUNTY WEST AND SOUTH OF THE GREAT BELT NORTH OF WEST CHESTER.

1. *Cope's Serpentine.* This is on the land of Caleb Cope, about a mile northwest of West Chester, and is referred to in C^4, p. 89, in a quotation from Rogers as Cobb's serpentine. I described this,

[166] *Second Geol. Survey of Pa.*, Annual Report, 1886, p. 1614.

in one of the papers referred to, as occupying a narrow stratum in a synclinal of mica schists overlying a rock, apparently of the ancient gneiss, though not so characteristic as to be beyond doubt, and lying a very short distance north of undoubted ancient gneiss.

Further examination has satisfied me that the rock underlying the steatite is not as supposed, but merely a portion of the belt of hard gneiss which lies north of the serpentine further east, and which outcrops on the Brandywine above Cope's bridge, referred to by Mr. Hall as resembling the rocks of southern Delaware county.[167] It seems to be but a local variation of the schistose gneiss, and is comparatively small in quantity.

Another occurrence of steatite, but of still less quantity, was observed about a half-mile north of Cope's, and the same distance east of Copeland schoolhouse, where a narrow belt of talc schist was embedded in the mica schist. These seem to have no relation to the great serpentine belt.

2. *Black Horse Serpentine.* About 1.7 miles west of West Chester the Strasburg road, having descended the gneiss hill on which that city lies, crosses Black Horse run about a half-mile southwest of the Cope locality and ascends a low hill on the summit of which stands the Black Horse Inn, an old landmark. This is referred to (C^4. p. 89) as follows: "A still more trivial locality of steatite is at the Black Horse tavern on the road to Taylor's ford.[168] It is on the same general line with the previously mentioned localities of magnesian rocks."

The rocks here are fairly exposed in the road cutting, and are microscopically heavy-bedded hornblende schist with massive hornblende, much of which has undergone deep decomposition. Under the microscope thin sections show besides the hornblende olivine and hypersthene, indicating a plutonic origin. In the decomposed rock the steatitic mineral occurs in seams, from the thickness of a knife-blade to an inch or more. No serpentine was

[167] "In the vicinity of Copesville, East Bradford township, the rocks exposed along the east branch of the Brandywine creek are a coarse micaceous gneiss identical with those on the southern edge of Delaware county. Syenite is found in large quantities in the micaceous gneiss at the north of Copesville. Its occurrence is similar to that as found in the vicinity of the White Horse Tavern in Ridley township, Delaware county" (C^4, p. 61).

[168] Probably intended for Copesville or Cope's bridge. I am informed that Taylor's ford is in another part of the county and that this crossing of the Brandywine was not known by that name.

observed nor any steatite except in the thin seams. This outcrop is unlike any other of the region. In parts the hornblende has a massive trap-like character, but other portions seem to be distinctly foliated with strike of N. 40° to 60° E., dip uncertain.

3. *Worth Serpentine.* This locality, noted by Rogers and barely mentioned by a quotation from Rogers (in C^4, p. 89), is of interest, inasmuch as the relation of the rocks so very closely coincides with what may be observed in Delaware county, the ancient gneiss axis being absolutely continuous. Like the Radnor serpentine, it forms a prominent hill, striking ± S. 40° W., dying down steeply westward at a small affluent of the East Branch of the Brandywine. The locality is on the Worth farm, about one mile S. 30° W. of Copesville, or Cope's bridge. To the south of it the gneiss is prominent, though not visible in place close to it. On the north a considerable dyke of trap, probably the diabase of the Conshohocken dyke, appears within 300 feet, and then the gneisses and mica schists dipping southeast or toward the serpentine. The visible outcrop is not over 1000 feet in length; it is visibly 300 feet to 400 feet broad. It is distinctly foliated and dips N. 30 to 40° W. 30° to 65°.

A curious occurrence here is a stratum of serpentine of no unusual appearance, but containing disseminated magnetite in such abundance as to exhibit strong polarity.

About a mile and a half southwest of the Worth serpentine the West Branch of the Brandywine and the Wilmington & Northern Railroad, which here follows its right bank, give numerous and good exposures of the gneiss on the southeast and of the schists on the northwest, but no serpentine is visible. A mile further southwest, near Northbrook, the serpentine again appears, and at this point on *both* sides of the gneiss, which is here only a quarter of a mile wide but forming a high hill. The outcrop of serpentine —or rather outcrops, for there appear to be two on the northwest side of the gneiss—have not, I think, been previously described.

They are inconspicuous and lie respectively S. 50° W. five-eighths, and S. 60° W. one-half mile from Northbrook, on a road running south-southwest, nearly parallel with and a little west of the Newlin-Pocopsin township line, from the Brandywine just west of Northbrook to the State road. Enstatite or bronzite accompanies the serpentine. About a quarter of a mile north of these

a greenish mica schist dips ±45° nearly due west. At Northbrook a road runs nearly south to the State road at Pocopsin Inn, a point about a half-mile northeast of these outcrops. Near this road the gneiss is exposed in place in the bed of a brook on the northeast. Southeast of it and close to the summit and to the State road signs of serpentine again appear, together with the feldspar porphyritic rock which appears at so many serpentine localities. The occurrence is so remarkable that I copy in full from my notebook:

South of Northbrook, heavy-bedded gneiss in bed of brook N. 15° W. 75°.

South of this, ascending a steep hill, no rock in place but abundant gneiss fragments for .2 mile. Then, at about 300 feet north of the State road at Pocopsin Inn, loose honeycomb quartz was seen, then as follows:

10′. Serpentine in gutter of road, not well exposed, but apparently in place;
20′. Concealed;
20′. Mica schists, decomposed, poorly exposed;
40′. Schistose gneiss, highly feldspathic and full of nodules of feldspar (probably orthoclase) mostly one-eighth to one-half inch in diameter, but some two inches, the rock much decomposed, dip ± 20° S.E. It varies from nearly mica schist to almost pure feldspar;
3′. Feldspar (?) decomposed into nodules, with a stratum ± 3 inches of a soapy schist;
50′. Mica schists with interbedded schistose gneiss, not porphyritic. Overlying this (topographically) is apparently the same rock decomposed, and, within three feet of the undecomposed, talc schist in loose masses;
50′. Mica schists, dip steeper southeast and then vertical, then ± 70° N.W.

These were observed on the westerly and higher side of the road, where the exposures were best. On the easterly side was talc schist, about ten inches wide, clearly intercalated in the mica schist and enclosing feldspar, decomposing apparently into the talcose material.

From this to the State road was concealed, but on the State road a quarter of a mile further west the serpentine makes a well-known and conspicuous outcrop, and here the porphyritic

schistose gneiss or granulite, with spangled schists, appears east of the serpentine and dips E. 10°.

West of this on the State road, close to a road leading northwest to Glen Hall, is an insignificant outcrop, to the west and north of which schists poorly exposed dip northwestwardly probably under 30°.

Going northwest on this latter road, and looking eastward, the westerly end of Brag Hill (gneiss) may be seen as a promontory. Close to the road running nearly west from Northbrook to the corundum mines, the schists form the summit of a high hill, on the strike of Brag Hill, and in this to the westward serpentine with enstatite or bronzite appears, with much aplite, granite and pegmatite, with some trap, covering an area over a mile in length and of uncertain width, probably between a quarter and half a mile wide. It is in this that the large quantities of corundum and accompanying minerals have been found for which Newlin is famous; large quantities of feldspar are now being obtained from surface openings.

This is the westernmost exposure of serpentine adjacent to the ancient gneiss, and it will be observed that as the gneiss disappears beneath the schists, the flanking serpentine seems to unite in this large outcrop directly in the strike of the gneiss.

We ought here to find evidence of the structure, but the dips in the schist are obscure. It is sure, however, that we have the continuous ancient gneiss from near Trenton to this point, and that on both sides of it for a distance of nearly twenty-five miles we have outcrops of serpentine of closely similar character, not continuous throughout, but often so for miles, and in all cases where outcrops can be observed very close to the edge of the gneiss. At times between the gneiss and the serpentine there can be found a thin outcrop of the spangled schists or gneiss, and especially the feldspathic porphyritic variety. Beyond the serpentine, on both sides, are the garnetiferous and spangled schists in large quantity, which, or the feldspar porphyritic varieties, appear to divide the serpentine whenever, as southeast of Malvern, at Sconneltown, and at Strode's mill, it appears in double outcrops.

Following the southeasterly margin of the ancient gneiss eastnortheasterly from the serpentine at Pocopsin Inn, we find the next outcrop at Sconneltown, about two miles southwest of West Ches-

ter, where the adjacent rocks are similar—the hard ancient gneiss on the northwest, the softer schists and very feldspathic gneiss on the southeast.

About a half-mile nearly southeast of the Sconneltown outcrop are those at Strode's mill. These are two, close together. The ancient gneiss is apparent within less than a quarter of a mile north of the larger outcrop on the right bank of Plum run, but the road from Sconneltown to Strode's mill does not expose the hard gneiss, but only soft schistose gneiss, some highly feldspathic. These have a dip of about 35° S.E. Within ten feet southeast of the serpentine is a small outcrop of the massive hornblende rock which appears at several outcrops of the serpentine. About .1 mile further southeast are schistose, very feldspathic gneisses with a coarse granite of reddish feldspar and quartz S. 70° to 75° E. 50°, then another outcrop of serpentine, followed by coarse gneiss dipping 30° to 50° N.W., beyond which schistose gneiss, feldspathic and hornblendic (but to all appearance not the ancient gneiss), dips S. 10° W. 20°, forming Osbourne's Hill, in which years ago a mine was opened for manganic oxide derived from the decomposition of a massive manganesian garnet.

About a mile further southeast is Brinton's quarry, which will be discussed hereafter as its serpentine appears not to belong to the range of outcrops under consideration.

From Strode's mill the border of the ancient gneiss passes nearly east-northeast, but along it no serpentine appears for some six miles. At this point, the southwest corner of Willistown township, is a well-known and extensive outcrop, where the Street road diverges from the Philadelphia and West Chester road. The ancient gneiss is to the northwest, but apparently separated from the serpentine by spangled schist containing garnets and pebbles (?) of quartz and feldspar.

About two miles to the eastward is the well-known "Castle Rock" of massive enstatite or bronzite, forming a precipitous cliff on the right (west) bank of Crum creek, while on the left is serpentine and much honeycomb quartz from its decomposition. East of this serpentine, which covers but a small area, is a narrow outcrop of the gneiss, followed by another outcrop of serpentine poorly exposed near the top of the hill, 1.5 miles west of Newtown Square, beyond which the gneiss again appears. Except of the

gneiss, all the prominent outcrops are on the south side of the Philadelphia and West Chester road. The gneiss is exposed in the road and on both sides of it. It is in this vicinity, but perhaps not far east of Willistown Inn, that the gneiss appears to project toward the west-southwest a prong which forms a high ridge south of the valley through which the Street road runs, and the floor of which is of schistose rocks. On Crum creek, which flows southeast, this prong is nearly two miles wide, and on its southeast border are the Blue Hill and Marple outcrops of serpentine, which can be traced northeast to a probable connection with the LaFayette belt.[169] South of the serpentine outcrops mentioned are a number of exposures in both Delaware and Chester counties. These are mostly small, scattered and, with few exceptions, insignificant compared with those to the northward. Those east of Chester creek have been fully described.[170] Those in Delaware county west of Chester creek are shown on Mr. Hall's map, C^5. All of them appear to be in the schists and schistose gneisses, and they are of rock, usually light-colored and much softer than that near the ancient gneiss, talc and antholite being often more abundant than true serpentine, like the southerly outcrops to the westward. Some show merely a small area of honeycomb quartz. On but few of them have quarries been opened. Probably the largest exposure is on the Smith's bridge road, .1 mile east of Elam. Here some quarrying has been done in a light-colored serpentine, very much jointed and showing abundance of slickensides, on the Husband farm; east-northeast of it .2 is hornblende schist.

Bullock's quarry, in Birmingham township, Delaware county, one mile west-northwest of Elam, shown on the map C^5 as serpentine, was not in serpentine but in limestone.

In southeastern Chester county somewhat similar outcrops occur. Of these the most important is that in which Brinton's quarry[171] has been opened in a pale-green serpentine, so uniform in texture and free from quartz that it is sawed into shape for building purposes by a toothed circular saw nearly as rapidly as if it were

[169] *Proc. Acad. Nat. Sci.*, 1885, p. 407.

[170] *Ibid.*, March 25, 1890, p. 100, etc.

[171] C^4, pp. 63, 298, 299; C^5, Plates xiii and xiv. Probably more serpentine for building purposes has been obtained from this quarry than from any other in the United States.

wood. After sawing probably two square feet of surface in about three minutes, the teeth of the saw were quite cool to the touch. The rock is much jointed, so that there is a great deal of waste, but much valuable stone is procured. A feature of the outcrop is a huge mass of feldspathic rock, looking like a dyke. It is mostly plagioclastic feldspar with tourmaline and a little quartz. Occasional beryls occur.

The nearest visible rock southeast of the serpentine is on the Street road about .2 mile from the quarry, a spangled gneiss in thin beds, the partings being nearly plane surfaces.

In 1892 a cut was made southward into the quarry, giving a good exposure of the adjacent rock on the north. Next to the serpentine was a narrow selvage of decomposing chloritic rock, then a highly schistose gneiss, with abundant feldspar in rounded masses, then a vein or dyke of coarse very feldspathic granite, of which the mica, probably originally biotite, is now Jefferisite, then a decomposing schistose gneiss dipping N. 40° W. 65°, or away from the serpentine. East of Brinton's, trivial outcrops are said to occur within a mile.

About two miles northeast of Brinton's and east-southeast of the old Pleasant Grove schoolhouse, fragments of a light-colored serpentine are abundant in the soil. A small quarry for building stone was wrought in this vicinity on the farm of Mr. James S. Rhoads. It is now filled in. All these are almost certainly in direct continuation of the serpentine at Brinton's quarry, which, however, does not appear on Chester creek, less than half a mile to the eastward.

West of the Brandywine and south of the margin of the ancient gneiss are several outcrops. Of these, the most conspicuous is that at Pocopsin Schoolhouse, Pocopsin township, about a mile west-southwest from the Brandywine at Lenape. A hard dark serpentine forms two quite conspicuous hills, surrounded apparently by schistose porphyritic gneiss, and accompanied by a coarse tourmaline-bearing granite. Nothing but the serpentine is well exposed. West of this, a well-marked valley, occupied by Pocopsin creek and by a parallel public road, leading from Lenape to Marlboroughville, trends a little south of west, very nearly parallel with the Street road valley and with the southeasterly boundary of

Pocopsin township. In this valley are two well-marked outcrops of serpentine.

One of these lies southwest of Locust Grove and about 2.2 miles west-southwest of Pocopsin Schoolhouse upon a small branch of Pocopsin creek, quite near its mouth, and has an apparent irregular southeast dip. One measured was S. 45° E. ± 80°. The outcrop is small, but a quarry was opened on it. The serpentine is much jointed and rather light in color. No other rock is exposed near by. A little less than a mile to the eastward is a quarry in mica schist S. 20° E. 40°.

The other lies 1.25 miles further west-southwest, and about a half-mile nearly south of Marlborough Meeting-house in East Marlborough township, very near the head of Pocopsin creek. It is interesting because contact is shown with the garnetiferous mica schist on the northwest, dipping S. 30° W. 30°. The schist near the contact seems to have been changed in part into serpentine, and the strike changes suddenly from southeast to east-southeast. The serpentine is of a dull yellowish green and has been quarried to a small extent.

The two localities are on a line about a mile south of the Pocopsin Inn serpentine, which is near the margin of the ancient gneiss. About half-way between is an outcrop of talc schist, north of limestone on the L. M. Larkin farm, near the Pocopsin-Newlin township line and about a mile south of Northbrook Station, Wilmington & Northern Railroad In the adjacent soil are abundant fragments of mica schist and gneiss, with some highly feldspathic gneiss and some decomposing hornblende rock.

About a mile and a quarter northwest of Northbrook Station, hence northwest of the ancient gneiss, on the Lamborn farm, is an outcrop of serpentine and steatite, the latter used by the Indians for the manufacture of pots. The outcrop is not large. South of it is a ridge of garnetiferous mica schist dipping S. 30° E. 20° to 30°, so that we have here a very remarkable repetition of the rocks of Radnor and Lower Merion.

Chester county.		*Delaware county.*	
N. Limestone Schists,	Poorhouse quarry.	Limestone Schists,	Stacker's quarry.
Steatite Schists,	Lamborn's.	Steatite Schists,	Judge Hare's.
Serpentine,	Northbrook.	Serpentine.	Radnor Station.
Ancient gneiss,	South of Northbrook.	Ancient gneiss,	South of Radnor Station.
Serpentine Schists,	Pocopsin Inn.	Serpentine	Rosemont to Lafayette,
		Schists,	Bryn Mawr.
S. Serpentine,	Pocopsin creek.	Serpentine and steatite,	Soapstone quarry belt.

This may be only accidental coincidence, but it is curious.

There is an outcrop of talc schist and steatite very close to the west line of West Bradford township on Buck and Doe run, about a quarter of a mile from its mouth and about a mile south of Mortonville. There is mica schist on both sides; dips of N. 20° E. 45° and N. 85° E. 50° were observed.

Very recently Mr. Walter J. Baldwin pointed out to me an outcrop of serpentine apparently within the hydromica schist, or on its southern edge. It is on the Steele farm, near the west line of West Bradford township and a mile and a half northwest of Romansville, on the second road north of the Strasburg road and the first road south of the Highland road. It is light green in color, weathering nearly white. Most of it is intersected by numerous irregular joint planes along which decomposition has begun. The masses not so intersected are very tough. It forms the nose of a hill on the south side of the road, and is visible about 1000 feet east and west and 400 feet north and south, the hill striking about S. 70° W. No adjacent rock is exposed, the nearest being the hydromica schist.

In the southwestern corner of Chester county, extending thence into Lancaster county on the west and into Maryland on the south and southwest, is a series of very extensive outcrops, perhaps the best known of any in the State, as in them were Woods' chrome mine, Lowe's mine, the line pit, etc., the extensive sand chrome washings and the mines of magnesite, deweyite, etc., which supplied Powers & Weightman, as a source of magnesia for many years, and also Bye's serpentine quarry in Harford county, Md.

The latter was opened on a very uniform compact serpentine, about five miles from Conowingo on the Susquehanna. It is trans-

lucent, and from a pale to deep green, taking a high polish and making a beautiful ornamental stone, but the quarry was not successful, probably owing to the great waste caused by the numerous joint planes.

An analysis by Dr. F. A. Genth, quoted in a circular of the company, is as follows:

Silicic acid,	40.06
Alumina,	1.37
Chromic oxide,	.20
Niccolous oxide,	.71
Ferrous oxide,	3.43
Manganous oxide,	.09
Magnesia,	39.02
Water,	12.10
Magnetic iron,	3.02

S. G., 2.668; hardness, 4.

For many years these serpentine areas furnished all the chromium compounds used in the United States except very small quantities mined in Delaware county. The region has, consequently, been more carefully studied than the others, and I can add nothing of importance to what has been published.[172]

An outcrop of serpentine wholly within the ancient gneiss, and the only one so located, unless possibly that east of Radnor Station, which, if within, is very near the border, was discovered in the spring of 1899 by Miss Ogilvie, a student under Dr. Bascom at Bryn Mawr College. It is located near the Red Rose Inn, north of the Spring Mill road, and about two miles east-northeast of Villa Nova Station, a little west of the old Gulf road, and near the source of Aramink creek. This would be probably three-quarters of a mile from the northerly edge and a half-mile from the southerly edge of the ancient gneiss. The rock has been quarried for road purposes; no contacts are visible. The serpentine is quite uniform, of a dull yellow-green color and not hard.

Whatever doubt there has been as to the origin of the serpentines, petrographic studies seem to prove that almost, if not quite all, are derived from the alteration of a basic igneous rock, peri-

[172] William Glenn, *Trans. Am. Inst. M. E.*, XXV, 481; Dr. Frazer, C⁴, pp. 341–345; Dr. Frazer, C⁵, p. 89, etc., 170, etc., 190, etc.; Prof. Fred. D. Chester: "All the rocks of this belt can be traced back to an original pyroxenic magma erupted through the azoic schists which surround the belt" (*Second Geol. Survey of Pa.*, Annual Report, 1887, p. 105).

dotite, amphibolite or pyroxenite, except in the comparatively few occurrences in limestone. In several of the outcrops in this region the unaltered mother-rock may be found in all stages of alteration, and this macroscopically. This may be seen at Rose's quarry, opposite LaFayette on the Schuylkill, and to the westward, and on the same belt near Darby creek and in Marple; near the corundum mines in Newlin, Chester county, and at Radnor. At most localities the original rock seems to have been an orthorhombic pyroxene —enstatite or bronzite. In the neighborhood of Glen Riddle, southwest of Media, some of the serpentine is after actinolite.

There are some facts in relation to the serpentines in this region which have received no adequate explanation:

1. The occurrence of the dark pyroxenite serpentine on both sides and close to or within the ancient gneiss from the Schuylkill westward, but not eastward. If due to the alteration of an intrusive igneous rock, its occurrence along a definite horizon is remarkable. If a sheet, it should be more closely continuous.[173]

2. The occurrence of parallel belts of peridotite serpentine separated by schistose rocks from the pyroxenite serpentine on both sides of the ancient gneiss.

3. The occurrence at many serpentine localities of an acid rock, chiefly of triclinic feldspar, in the form of veins or dykes. Can it be explained by magmatic differentiation ?

4. The occurrence at many localities of a massive amphibolite on the southeasterly side of the serpentine outcrops, at Willistown, near Newtown Square, Strode's mill, the soapstone quarry near LaFayette and the outcrops in southwest Chester county, resembling in this the dunyte beds of North Carolina.[174]

Besides the chromium, which is common in the enstatite serpentine, nickel has been found in very small quantities as sulphide, millerite and hydrous silicate, genthite, at the soapstone quarry, near LaFayette, and as genthite and also in wad and in pimelite northwest of Radnor Station.

Since the above was written I have found on the serpentine south of Newtown Square, Delaware county, a very dark-brown, almost black rock, apparently wholly unaltered and which appears to be

[173] Cf. *Proc. Acad. Nat. Sci.*, Phila., 1890, pp. 114, 118, etc.

[174] Dr. Julien, *Proc. Boston Soc. Nat. History*, Vol. XX, p. 11, Dec. 6, 1882.

hypersthenite;[175] some of the crystalline masses composing it are nearly an inch across.

Pegmatite.

In the schists and gneisses, particularly in the southeastern part of the area, are more or less irregular masses of pegmatite, usually composed of microlin, albite, quartz and muscovite, the minerals ocurring in abundance relatively as named, with biotite, tourmaline and garnet in small quantity, and more rarely beryl, autunite and other uranium minerals.

Some of these masses seem to occupy fissures in the gneiss with well-defined walls; others to be lenticular masses wholly surrounded by the gneiss, while others seem to grade imperceptibly into the gneiss. The first may be seen at Deshong's quarry on Ridley creek, northeast of Chester, where a large mass is exposed showing sharp but very irregular contacts with the gneiss. In this quarry, as indeed in all the quarries of that vicinity, pegmatite was comparatively abundant, but usually in isolated masses, many of them quite small. It occurred also in the Fairmount quarries, at Frankford, and indeed at almost every place near Philadelphia and Chester at which quarrying has been done extensively. It occurs in large quantity in the porphyritic gneiss, composed almost wholly of a reddish and a chalky white feldspar, with very little quartz and still less mica, with tourmaline rarely and none of the rare minerals.

In the more schistose rocks to the northwestward it is comparatively rare, though a large mass was quarried immediately southeast of the ancient gneiss near LaFayette, Montgomery county, almost wholly feldspar.

Southwest of Philadelphia it occurs at a number of localities, at some of which it has been mined extensively, mostly for use by manufacturers of china, etc. Most of these are open cuts, but at the largest, near Elam, southwest of Brandywine Summit, there are extensive underground workings. Most of these have been described by Prof. Thomas C. Hopkins.[176]

There are some localities in addition to those referred to by Prof. Hopkins that may be mentioned:

[175] Dr. Bascom in a private communication identifies it as hypersthene.
[176] *Journal Franklin Institute*, July, 1899, Vol. CXLVIII, No. 1.

1. Chandler's Hollow. This was quarried about 1860–70, and yielded besides feldspar much muscovite, most of which was filled with markings of magnetite, making fine specimens, but ruining the mica for commerce. This was not far south of the Brandywine Summit mines, southwest of Elam.

2. Craig's Pits, about a mile and a quarter southwest of Chadd's Ford. This is an open cut into the side of a hill; the feldspar seems to be an irregular lenticular mass or vein with considerable muscovite. The feldspar seems of good quality and a very large amount has been quarried.

3. Butler's Pits, one-half mile south-southeast of Fairville Station. These are in level ground, and have been excavated to and below water level. From the size of the opening an immense quantity of feldspar must have been taken out, but when visited in 1897 work had ceased.

4. Swayne's Quarry. This is about half a mile south of Butler's. The pegmatite seems to be an irregular chimney-like mass, which has been followed to a depth of nearly one hundred feet. At this place the feldspar was subordinate to the muscovite, which when the mine was in full operation was obtained in crystals, some measuring eighteen inches across and being over a foot in length.

Much of it had the magnetite markings, but a large amount of valuable mica was obtained.

West of Avondale as well as north of it are several outcrops of pegmatite, one of which, immediately east of and in contact with the limestone of the Avondale lime and stone quarry, was wrought to some extent, but not largely. It seems to be a well-defined vein or bed, striking nearly northwest and southeast. At nearly or quite all of these the chief feldspar is microclin.

Adjacent to the serpentine areas are often outcrops of feldspar, generally, if not always, triclinic. Two only of these are now wrought, those in Newlin township near Unionville, and at Sylmar in West Nottingham. Some of the other outcrops have yielded cabinet specimens, but have not been tried commercially. That a mile west of Media has yielded fine sunstone and moonstone, beryl and columbite, some of the moonstone and beryl furnishing gems. That near Dismal run furnished a nearly transparent variety, as did also that at Brinton's quarry, Westtown, Chester

county, and Blue Hill, Upper Providence, Delaware county, which furnished also the baryta-feldspar cassinite.

The feldspar from Sylmar resembles that obtained at the famous Dixon's quarries (and Way's quarry) in New Castle county, Delaware, but is remarkably tough and not easily cleaved, so that before crushing and grinding for market it has to be roasted.

Besides the locality mentioned by Prof. Hopkins near Boothwyn Station (Bunting's quarry, Bethel township, Delaware county), there are many outcrops in that township and the adjoining one, Chichester, which have been explored to a slight extent for their well-defined crystals of feldspar, garnet and beryl. One remarkable one south of Boothwyn was very slightly exposed in low ground on a small affluent of Naaman's creek.

It consisted almost entirely of microclin and quartz, but almost all the microclin was well crystallized, the crystals with rather rough surfaces, but sometimes complete and doubly terminated. They varied in length from an inch to a foot and were usually about twice as long as broad. Quartz occurred in the feldspar in the usual graphic granite form and also filled the interstices between the feldspar crystals. One specimen was nearly an octahedron in shape, with deep grooves parallel to a basal plane. This would seem consistent with the theory that the feldspar crystallized first, the quartz occupying the space remaining; but from the same place I have, imbedded in the microclin, a crystal of quartz of its own hexagonal form.

A little west of Boothwyn was a narrow vein or dyke about two feet wide in decomposed schists, composed of quartz and feldspar, in which were found fine crystals of garnet; this had perfectly straight well-defined smooth walls, striking N. 35° E. nearly vertical.

The feldspars of this region are worthy of careful and systematic study.

At a number of localities the pegmatite has decomposed and become wholly kaolin. Many of the pegmatite outcrops show much kaolin, but at none of the kaolin outcrops have I seen undecomposed pegmatite. There is, however, much intermixed quartz and mica, but both almost always in very small masses, little more than sand.

There is, however, no appearance of water sorting, the quartz,

mica and kaolin being evenly intermixed. It would appear, therefore, as if the pegmatite which gave rise to the kaolin was a much finer grained rock than that quarried for its feldspar.

Prof. Hopkins, in the paper already referred to, has described the kaolin deposits. There is one curious fact to which I would call attention—the occurrence of limestone with nearly every kaolin deposit, viz., near Glen Loch (Chester Valley), Kaolin (Broad Valley), near Avondale, Hockessin, Elam, and also at Peach's kaolin mines in Delaware, south of Hockessin. At all these six localities limestone occurs close to the kaolin. The Wagontown locality may be an exception, but inasmuch as the Cambrian sandstone which underlies the limestone occurs just north of Wagontown, the probability is that it is not an exception, simply that the limestone is not exposed.

Trap Dykes.

There are in Pennsylvania, southeast of the vicinity of the Red Rocks, two well-defined trap dykes, besides a number of exposures of igneous rocks not yet reducible to a system.

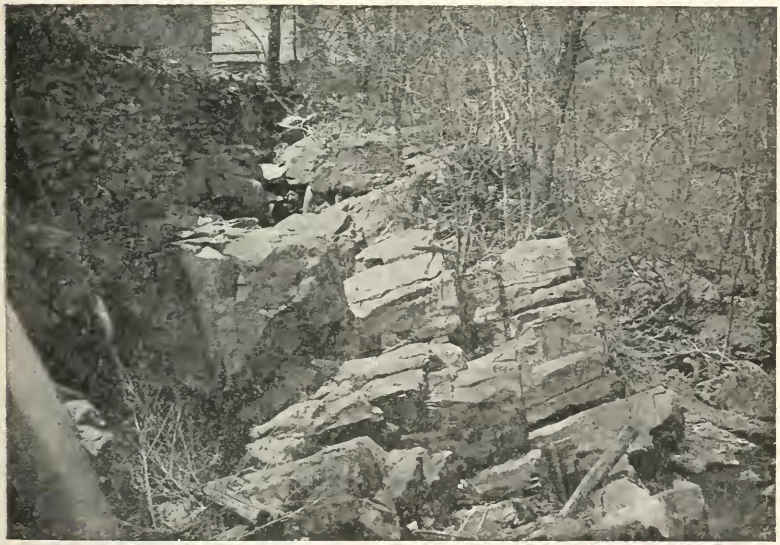

Fig. 8.—Columnar Diabase. The Gulf, Montgomery Co., Pa.

The easternmost of these is the well-known Conshohocken trap

dyke, specially studied by Prof. H. Carvill Lewis, and thought by him to have a linear extension of some eighty miles, though usually less than a hundred feet in breadth. Its best exposures are at Conshohocken and at Gulf creek. At West Conshohocken there was exposed an offset cutting the hydromica schists to the eastward of the main mass. It was only two or three feet in breadth. No change in the adjacent schist was observed.

The columnar structure is best shown at Spring Mill and at the Gulf, as well shown in Fig. 8, from a photograph taken by Dr. Charles Schäffer. A remarkable feature is the absence of any noticeable change in the rocks cut by it. Its strike is very nearly that of the limestone, mica schist and hydromica schist, but it passes through all of them. Near Flourtown it is in the limestone of the Plymouth Valley. It then crosses acutely from the north to the south side of the hydromica schist hill, and in the cut of the Schuylkill Valley Railroad at Conshohocken is in the southeasterly limestone (that of Cream Valley). Directly across the river, in West Conshohocken, it is again in the schist.[177]

Near the Delaware county line it crosses the limestone, being north of it at the Gulf, and south of its course north of St. David's Station, where it is in or on the margin of the garnetiferous mica schist, and this seems to be its position also at Wayne, where it is exposed in the railroad cut northwest of the schist and southeast of Cambrian sandstone. West of Wayne the outcrops are not continuous, but when found are in the comparatively low ground between the ancient gneiss hill on the southeast and the hydromica hill on the northwest. In Willistown township, Chester county, immediately west of the Easttown line, it appears on the road next south of the State road, and apparently exists in three separate branches, one north of the serpentine, the next in it and the next south of garnetiferous mica schist. All are within a thousand feet. The dyke crosses the State road close to the easterly line of East Goshen, and thence westward appears to be on the north border of the serpentine, though north of Goshenville it cuts it. Northwest of the Gen. Greene Hotel the serpentine appears to end in a rounded hill and the trap is concealed. South-

[177] The exposure on the east side of the river indicated that the limestone underlies the schist at that point, both having, however, nearly the same dip as if folded or rather crumpled together.

west of this the trap may be traced, but no serpentine until the east line of West Goshen is crossed. About a mile west of this line, and near the Pennsylvania Railroad, the serpentine again appears in great quantity, with the trap on the northerly side. Thence westward the trap skirts the north side of the serpentine ridge to its termination near Hoopes' mill. On the road passing the mill, the continuation of New street, West Chester, exposures are poor, but loose masses of serpentine are north of trap masses; this is near the westerly line of West Goshen. In East Bradford, which adjoins, the trap is prominent on the side of the hill north of Cope's limestone quarry and south of Copeland Schoolhouse. A half-mile to the westward is the East Branch of the Brandywine, on which just north of Cope's bridge loose masses are abundant, but the outcrop here appears to be somewhat south of the strike of the easterly outcrops. West of Cope's bridge it is conspicuous along the Strasburg road toward Marshallton, West Bradford. Southeast and southwest of Marshallton it is exposed nearly in line with the outcrops on the Strasburg road, but also northwest of the serpentine at Worth's in East Bradford, about a mile southeast of Marshallton, considerably south of the outcrops on the Strasburg road. West of this is the valley of Broad run, but I am not aware of any exposures until the Newlin serpentine is reached. This is about two miles west-southwest of the outcrops near Marshallton. Going west-southwest the first exposure is on a small affluent of the West Branch of the Brandywine about three-quarters of a mile west of Northbrook. Close southwest of this are two roads about a quarter of a mile apart leading nearly south from Glen Hall to the State road. On the easterly are serpentine, pegmatite and mica schists, while on the westerly is a large outcrop of trap, in loose masses only. Between these roads is the locality famous for its large beryls, giving name to the elevation, Beryl Hill.

West of Beryl Hill is Corundum Hill. On its easterly flank and near the summit there is much trap, but only in loose fragments apparently within the serpentine.

About a mile and a half nearly southwest of Corundum Hill, and about a half-mile southwest of Unionville, there are outcrops along the State road a little northwest of the diverging from it of the Little Street road.

Thus far the outcrops are probably of the Conshohocken dyke much interrupted and somewhat curved, but the outcrops to the southwest are scattered and not referable to a line. The northeastern one is about two miles nearly west of that last mentioned, and a little west of the E. S. Baily limestone quarry west of Marlborough Inn (Upland). This also is on the State road, and is about a mile west of the east line of West Marlborough. On the same road a mile further west is another outcrop.

About a mile south of the State road is the Street road, on the line between West Marlborough and London Grove townships. Along this road are several outcrops, the easternmost nearly south of the outcrops on the State road last mentioned. The next is a half-mile further west near Woodville, the next three-quarters of a mile further west and a little east of the Pomeroy & Newark Railroad, both on the Street road and on a lane running south from it.

All these outcrops west of Unionville are of loose masses only and none of them are extensive. To the southwest are other similar outcrops, some of which are probably continuations of the dyke next to be described.

The Downingtown Dyke.

This dyke was described[178] as extending in a nearly straight line from a bold outcrop on the Brandywine, over twenty feet high at Downingtown, in a south-southwest direction into Penn township, being largely exposed only occasionally, as on the Brandywine in Downingtown and on the Pennsylvania Railroad a quarter of a mile west of Downingtown Station, where a cut some twenty feet in depth has been made through it, but clearly to be traced by intermediate loose masses. It is here probably 125 feet in width, with limestone visible ten feet east of it and very little further west of it, and strikes about N. 15° E.[179]

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[178] Rand, *Proc. Acad. Nat. Sci.*, Philadelphia, 1895, p. 540.

[179] Dr. Frazer, *Proc. Acad. Nat. Sci.*, 1896, p. 206, apparently regards my brief description of this dyke as a reflection upon his work, saying that "he refrained in a great many instances from connecting together scattered localities where trap fragments occurred, on the assumption that these represented a dyke, because he was often unable to assure himself that these fragments where anywhere near the place of their origin," and, further, "the second dyke which begins in Downingtown is probably the same to which the following reference is made (C⁴, p. 274); at several points on the

Recently Mr. Walter J. Baldwin, formerly of Romansville, and now Professor in the Manual Training High School of Brooklyn called my attention to the fact that the dyke does not end with the outcrop on the Brandywine, and took me to a series of outcrops extending in a north-northeast direction for a distance of three miles up and over the summit of the North Valley Hill, the trap being in a nearly straight narrow line and in quantity. For this distance there seems no reasonable doubt of the continuity of the dyke.

The road to Lionville diverges nearly north from the Lancaster turnpike at a point about .7 mile east-northeast of Downingtown railroad station. After going north a little over a half-mile, it turns north-northeast. Near this bend the dyke may be seen crossing the bend—*i.e.*, crossing the road twice and bearing a little more northwardly than the road. A quarter of a mile or less beyond this curve, a road goes northward through the woods. The dyke crosses this road, a little north of the road to Lionville. Further north there is an east-and-west road, on or very near the north line of East Caln township. On this road, about a quarter of a mile east of the woods road, it is again apparent on the land of Jacob Lewis, and Mr. Baldwin informed me that it occurs also on the intermediate land of Clara Fox. Beyond this I did not follow it, but Mr. Baldwin states that he has traced it across Uwchlan township, south of the graphite mines near Byers' Station, across West Vincent, crossing the two branches of Birch run a little west of Birchrunville, crossing French creek at Cook's ford in East Vincent township, and close to Brownback's Church on the Ridge road in East Coventry, the Schuylkill at Frick's lock below Sanatoga Station, and through Sanatoga Park to the

road leading south from the Downingtown railroad station occur fragments of trap."

In the paper referred to the writer intended and made no criticism of any one, but it seems to him that to identify "fragments of trap" on the road south of Downingtown Station with a dyke more than a hundred feet wide, quarried to a depth of many feet, west-northwest and southwest and not south of Downingtown, is possible only upon the assumption that Dr. Frazer never saw the exposures. No geologist can be expected to see everything. It will be many years before it will be difficult for new facts to be discovered.

The writer would also contend that in a non-glaciated region numerous trap masses in a straight line with a large and unmistakable dyke, all being of a uniform coarse diabase, are evidence of connection though possibly not of the absolute continuity of a dyke.

large outcrop at Pruss' Hill, Montgomery county. If the dyke is continuous, of which there seems little doubt, it is triassic diabase, an offshoot from the great outbursts through the Red Rocks near Pottstown, and must be more than thirty-four miles long. Near Downingtown, concentric or boulder decomposition is well shown in the sides of the railroad cut.

Southwest of Downingtown the dyke is exposed at intervals toward and at Mortonville, also on Buck run and northwest and southwest of Doe run village, thence almost continuously and very largely to the south bend of the Pomeroy & Newark Railroad. Thus far there seems no reasonable doubt that all the outcrops should be referred to one dyke. The next two are probably, but not certainly, of the same; one of them is on the line between London Grove and Londonderry townships, very near the northwest corner of Penn, and about two miles west of Chatham. It is small, as also is the next, a mile south-southwest on the road from West Grove to Daleville, .1 mile east of Townsend's mill, but these probably belong to the same.

The next two are about five miles west-southwest on branches of Big Elk creek, respectively a half and three-quarters of a mile southwest of Lincoln University.

The rock at all these outcrops is a diabase. That of the Conshohocken dyke, uniformly fine-grained in texture, has been described by Dr. Bascom.[180] That of the Downingtown dyke is much coarser in grain, and very much alike at all the outcrops. That near Baily's quarry is of much finer grain, finer even than that of the Conshohocken dyke, as is also that east of Townsend's mill, while that west of Chatham and also that at the Street road and Pomeroy & Newark Railroad is intermediate.

That of the easterly outcrop on Big Elk creek seems to have much less feldspar than the others, while that of the westerly shows a coarse variety and also one very fine-grained.

Inasmuch as the coarseness or fineness may be due simply to slower or more rapid cooling it cannot be regarded as an important feature. Indeed, as a rule we should expect to find a coarser grain in the middle portions of a dyke and finer towards the edges, as indeed is the case at Downingtown, but the persistency of the character in the Conshohocken and Downingtown dykes is remarkable.

[180] Dr. F. Bascom, *Proc. Acad. Nat. Sci.*, Philadelphia, 1896, p. 220.

In the ancient gneiss are numerous dykes of trap, usually small and not to be traced any distance. Some were very clearly exposed in Johnson's quarry at Wayne. Here the trap, a fine-grained diabase, was from an inch to a foot in breadth, and could be seen to fork, to include masses of the gneiss, etc. Some of the dykes are hornblende schist, and are suggested by Dr. Bascom[181] to be altered diorites. Dykes of norite also occur, one near Van Artsdalen's quarry in Bucks county,[182] and one on the property of Miss Brown near the crossing of the Lancaster turnpike by the Radnor and Chester road, about .3 mile south of Radnor Station, identified by Dr. Bascom. Thin sections shown by her before the Mineralogical and Geological Section of the Academy of Natural Sciences show very beautifully the reaction rims of garnet around the crystals of pyroxene. About a third of a mile northwest of Radnor Station occurs a diabase (determined by Dr. Bascom) in the ancient gneiss, of coarse texture and having a reddish tint. Besides those mentioned there may be named the following prominent outcrops:

Railroad cut east of Radnor Station.

Erben's, Ithan creek, northwest of the Radnor and Chester road, Radnor.

Ellison's, Ithan creek, north of the Roberts' road.

Montgomery avenue, east of the Spring Mill road, Lower Merion.

State road, west of Pocopsin Inn, East Marlborough township, Chester county.

All these are apparently diabase, or diorites altered into hornblende schist.

In northern Chester county, besides the great outcrops of diabase in the north, there are scattered outcrops which remain for further examination. The more important may be mentioned:

1. Williams' quarry, near Aldham, Charlestown township, Chester county,[183] a gabbro in a very distinct dyke about 100 feet wide with porphyritic feldspar crystals.

2. A porphyry, near Barneston, Chester county.

3. South of Honeybrook, two outcrops, the northerly weathering

[181] Private communication to the author.

[182] Dr. J. F. Kemp, *Trans. N. S. Acad. Sci.*, Vol. XII, p. 71, February, 1893.

[183] *Proc. Acad. Nat. Sci.*, Philadelphia, 1895, p. 540.

white and looking like chalk flints, instead of the usual rusty yellow.

4. Beaumont's quarry, near Glen More.

5. J. H. Schrack's, West Caln, altered diorite, about three-quarters of a mile north of West Caln Meeting-house.

Other Igneous Rocks.

When we shall have a careful microscopic study of sections of the rocks of this region doubtless many rocks now doubtful will be found to be igneous or derived from igneous rocks, but at present a few only can be identified.

Prominent among these is the gabbro which, entering the State from Delaware, itself, with its accompanying hornblende rocks, spreads over much of the southeastern part of Delaware county, and apparently sends tongues into the mica schist and gneiss areas. Surface decomposition renders accurate mapping almost impossible. Some exposures, as near Concordville and Locksley Station, Delaware county, look as if comparatively thin dykes or sheets had been intruded into gneisses, after which both had been folded and crumpled.

The gabbro proper is well exposed at Claymont, Del., just over the line. A variety consisting almost wholly of a triclinic feldspar forms a part at least of Cedar Hill, in Bethel township, near the northwest corner of Chichester. In this region pegmatites are abundant but not well exposed.

There are exposures of a trap-like rock in Middletown township, Delaware county, about a mile northwest of Lima. The large loose masses forming the outcrop extend N. 60° W. nearly a half-mile.

A still smaller outcrop occurs in Edgemont township, one mile northwest of Cheyney Station, about two feet wide, and striking near north and south in hornblende and feldspathic gneiss.

Conclusion.

In the whole region southeast of the Red Rocks three localities only are known to have yielded fossils in rocks in place. The North Valley Hill sandstone in some places, notably west of Val-

ley Forge, shows abundance of *Scolithus*. The same fossil was found by Dr. Frazer at Avondale, Chester county.

Fossiliferous pebbles occur in the Delaware river gravels, also on the northeast slopes of Barren Hill, where *Scolithus* was found abundantly in large pebbles of the Cambrian sandstone, the source of which is obscure. They were exposed by the digging out of material for the Roxborough reservoir.

There should be mentioned also the fossils found in Shainline's quarry south of Henderson Station, referred to on page 204. In 1899 Mr. Lewis Woolman discovered in the limestone of this quarry what appear to be fossils resembling some of those in the orbicular quartzite. They were exposed by the weathering of the rock. Mr. Woolman thinks them suggestive of the flat-coiled forms such as *Raphistoma*, etc., rather than the elevated spiral forms like *Murchisonia*.[184]

The important locality is that described by C. D. Walcott, *Amer. Jour. Science*, XLVII, January, 1894.

It is north-northeast of Gap, Lancaster county, Pa., where in a sandy stratum in the limestone fragments of *Olenellus* and a species of *Obolella* were found. These identify the limestone of the Pequea Valley, a part of the great Lancaster county limestone region, with the Cambrian. As there seems no reason to doubt the identity of the limestone of the Lancaster and Chester Valleys, this would seem, as stated by Mr. Walcott, to identify the Chester Valley limestone as Cambrian, and the underlying sandstone as Lower Cambrian.

Accepting, then, that the sandstone of the North (Chester) Valley Hill is lower Cambrian, are we justified in assigning the scattered outcrops of similar rock to the same? It must be admitted that lithological evidence is untrustworthy, but in this case we have a peculiar rock, not only in the constituents, but also in its aggregation, and also in the fact that its characteristic tourmalines are always stretched and broken. The possibility that such rock should occur abundantly at two different horizons is remote.

Not only is there the lithological evidence, but also the stratigraphical, that the peculiar sandstone is almost always overlaid and underlaid by schists, and that above the upper schist almost invaria-

[184] Personal communication to the author.

bly a limestone is found. I think, therefore, there is little doubt that all the limestone and tourmaline-bearing sandstone may be considered of Cambrian age.[185]

The schists and gneisses present a more difficult question, which may be subdivided:

1. the age of the hydromica schists of the South (Chester) Valley Hill—in other words, are they above or below the limestone?

Dr. Frazer believed the schists to have been uplifted by a fault running along the south side of the valley, and that the southerly limestone was probably once continuous over the South Valley Hill.[186]

This hypothesis necessitates making the hydromica schists continuous with the very different rocks of the North Valley Hill, at times only a little over a quarter of a mile off, each having a thickness of certainly much over a half-mile, which constituted one of the gravest objections to Prof. Rogers' theory that the valley was a synclinal and the north and south hills of the same age, the sandstone of the north hill represented by small sandstone outcrops on the northerly foot of the south hill, the lower primal slates by the hydromica schists. This view has not been held by any later geologist and need not be discussed further.

Mr. Hall, demonstrating the synclinal structure of these schists at their northeastern end, where they very clearly lie in a basin of the limestone, which in its turn is surrounded north, east and south by the sandstone, and it by the ancient gneiss, argued that its continuation westward must be a synclinal overlying the limestone; the underlying synclinal of the limestone, however, is shown in his sections in C^6 to extend to the left bank of the Schuylkill only, on the right bank and also a mile to the westward to be cut off by a fault, the syenite underlying the limestone and in depth abutting against the hydromica schists at the fault line. Had Mr. Hall found the sandstone south of the limestone at Gulf Mills, I believe his sections G^1 and H would have conformed at this point to his section G.

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[185] There is confirmation in Dr. Frazer's interesting discovery of *Scolithus* in the sandstone adjacent to the limestone in London Grove township south of Avondale. C^4, p. 324.

[186] C^4, p. 303.

Prof. Lesley, agreeing with Mr. Hall as to the structure east of the Schuylkill, agrees in part with Dr. Frazer that at or west of the Schuylkill a great fault raises rocks *underlying* the rocks of the North Valley Hill belt above the surface to form the South Valley Hill.[187]

If this fault really exists and is of magnitude so great and so extensive east and west, it is strange there is not clearer evidence of it. Would it be possible, if it exists, for the dips in the limestone and the hydromica to agree as well as they do? Thus Dr. Frazer gives (p. 269) "along the south border of the Salisbury township limestone belt . . . . S. 10° E. 70° gneiss" (layers in limestone, p. 268), "S. 10° E. 40°; mica schist S. 53°, S. 15° E. 85°. . . . . The dips in the eastern part of the township are S. 10° E. 80°, S. 10° E. 60°, S. 30° E. 60°, S. 60° to 80°, etc."

"East Caln . . . . the dips in the belt of mica schists which passes south of the limestone vary in strike from E. 10° N. to E. 30° N. and from 80° to vertical. Some of the dips in the limestone are as follows: S. 10° E. 85°, S. 10° E. 60°; strike E. 10° N. vertical (= dip S. 10° E. 90°)," pp. 273, 274.

"West Whiteland . . . . schists ± S. 10° E. 80° . . . . limestone . . . . shows very constantly throughout its entire extent dips of S. 10° E. 70° to 85°," pp. 274, 275.

"East Whiteland . . . . Indian King road" (which is on the hydromica hill) . . . . "the dips at first all lie between or near S. 10° E. and S. 30° E. ± 80°." An exception is noted: "Along the main track of the Pennsylvania Railroad numerous dips in the same strata agree at about S. 10° E. 75°."

Dr. Frazer then gives dips in the limestone S. 15° E. 85°, S. 15° E. 80°, S. 15° E. 75°, S. 15° E. 85°, S. 20° E. 78° (pp. 275, 276).

These dips with others are tabulated in C⁴ (pp. 119 *et seq.*). If a fault exists it should be brought out by these tables, but they seem to show greater accordance than is common through this region, particularly on pp. 121, 122. Sixteen pairs of southeast dips being tabulated, seven agree, two show western convergence, seven eastward convergence. The table of dips is remarkably accordant. Abbreviated it is:

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[187] *Final Report*, I, 174.

		In the Schists.	*In the Limestone.*
Northward,	73° and less, . .	3	2
	85° to 90°, . .	4	4
Southward,	80° to 85°, . .	8	9
	70° to 80°, . .	7	7
	60° to 70°, . .	1	6
	50° to 60°, . .	4	2
		27	30

The arguments in favor of the fault seem to locate it at the north foot of the South Valley Hill.[188] By Prof. Lesley's theory it must be sufficiently profound to uplift the schists from a position beneath the North Valley Hill rocks, and by that of Dr. Frazer to uplift some two miles of schists. What becomes of it eastward and westward? Near King of Prussia the straight southerly line of the limestone ends, the hydromica curves gently southeast, forming two promontories, the limestone following, forming, as it were, a bay extending more than a mile south of a line in prolongation of the north foot of the hill in Chester county.

At McFarland's mills, where the Gulf creek flows northward through the hydromica schist hill, the margin resumes its east-northeast direction to the Schuylkill, still bordering as before the hydromica schist hill, which has narrowed to less than half a mile. A fault, to satisfy the conditions, would be of incredible shape.[189]

Mr. Hall's view that the hydromica schists are synclinal over the limestone was controverted by Prof. Lesley:[190]

[188] "The existence of such a fault would make it easier to comprehend the very extraordinary straightness of the south edge" (C^4, p. 113).

"Valley limestone, ... terminating eastward at Willow Grove in Montgomery county and westward at Quarryville in Lancaster county. Its extreme length is fifty-five miles in an almost perfectly straight line N. 18° E." (C^4, p. 112).

Mr. Hall's map C^6 shows clearly that east of the King of Prussia the line is very far from straight. Particularly is this true of the portion just west of the Schuylkill.

[189] Rand, *Proc. Acad. Nat. Sci.*, Phila., 1892, p. 445.

[190] C^4, 115 *et seq.*, who sums up the arguments pro and con briefly as follows:

In its favor—1. The acknowledged synclinal structure in Montgomery county.

2. The apparent necessity for considering it synclinal at Quarryville.

3. If synclinal "we can comprehend the existence of outlying troughs of limestone still further south."

4. The fact (?) that the limestones at the foot of the south hill are non-magnesian.

Against it—"Merely transferring the difficulty a few miles south, viz.: to the southern edge of the talc mica schist belt."

The *first* argument in its favor is so cogent as to be irresistible in the absence of a most remarkable and almost impossible fault.

The *second* is of force if we admit that the limestone cannot thin out, but as we find it does become exceedingly thin in some places compared with others adjacent, why may it not thin out and disappear under the hydromica, which would then rest upon the newer schists and gneisses ?

The *third* is not of great force. The southerly outcrops can be reconciled with any of the theories.

As elsewhere stated, Dr. Frazer thinks them an argument in favor of his theory.

The *fourth*, in view of the fact that the composition of the limestone varies so greatly, would require many more analyses to establish its basis, and certainly the arguments in C[4], pp. 103 and 117, are fallacious, for the "talc mica" contains little or no magnesia and cannot properly be called "intensely magnesian."

The argument against it seems rather to be in its favor, for it admits a line of limestone outcrops consistent with Mr. Hall's theory, giving them, however, no weight because they do not compare (in extent it is to be presumed) with those of the valley.

A glance at Mr. Hall's map in C[6] shows very plainly the admitted synclinal of the limestone northeast of the Schuylkill, the northerly leg two miles in width, the southerly less than one thousand feet. Even the latter, I think, is excessive. This is roughly as ten to one. Now as the Chester Valley limestone narrows to a quarter of a mile and perhaps less, the corresponding width of the southern leg would be but 132 feet, a width that is certainly much exceeded at the Poorhouse and Guest quarries. The narrower the outcrop, too, the greater the probability of concealment by the erosion of the limestone and the falling in of the adjacent rocks.

But not only do we find the limestone, but also accompanying it the sandstone, in scattered outcrops and very thin, it is true, but with its peculiar and definite characteristics.

It is true we meet with one difficulty: to the eastward the sandstone is southeast of the limestone and close to it; to the westward, to the northwest of it with an area of schists between. Exposures are not good and no explanation at present appears.

It will be noticed that in southwest Chester county that the sand-

stone, while at somewhat varying distances from the limestone, is much closer to it if regarded as underlying. If so regarded we have here five successive outcrops of limestone underlaid by sandstone within five miles, all dipping nearly alike. The explanation of this must be by abler hands than mine. Repetition by close folding is not likely with dips so regular and gentle; of faults there is no evidence.

2. The Age of the Mica Schists.

A. Can they be clearly distinguished from the hydromica schists?

As already stated, there is no difficulty in tracing a line with gentle curves northwest of which are hydromica schists only, while to the southeast are the mica schists. That the hydromica schists widen westward and attain a width of twelve or thirteen miles on the Octorara[191] is not the fact, unless no distinction be made between the soft smooth nacreous and unctuous schists of the South Valley Hill and the hard rough mica schists well exposed on all the creeks from east of the Brandywine to west of the Octorara. The following table of dips in the two rocks is instructive:

Locality of Mica Schist.	*Dip Mica Schist.*	*Dip Hydromica Schist.*	*Locality Hydromica.*	*Distance Apart of Measured Outcrops, Miles.*
West Conshohocken,	S. 28° E. 74° S. 20° E. ±90°	S. 15° E. 85°	West Conshohocken,	0.2
Near Water Works, Eagle Road, Radnor,	S. 23° E. 70°	S. 10° E. ±90°	Creek South of same,	0.1
W. of Greene Hill Station, W. Goshen,	S. 23° E. 60°	S. 10° E. ±90°	S. of Kirkland Station.	0.8
Wrangle S. H., W. Goshen,	S. ±25° E. 50°	S. 40° E. ±90°	1 mile N. W. of Wrangle S H.	1.0
McMinn's Mill, E. Bradford,	S. 25° E. 45° S. 30° E. 60°	±90°	Half mile N. of McMinn's,	0.5
Hawley's Mill,	S. 35° E. 45° S. 70° E. 25° S. 45° E. 40° S. 45° E. 65°	S. 40° E. 85° 90°	North of Hawley's Mill,	0.1
Broad Run,	S. 15°	S. 40° E. 70°	Broad Run,	1.
West Branch near Modena,	S. 20° E. 50° S. 10° W. 20°	S. 30° E. 55°	Opposite side of creek,	0.2
Buck Run N. of Newlin Sta.,	S. 25° E. 35°	S. 50° E. 80°	Buck Run N. of Newlin Sta.	0.1

[191] C⁴, p. 14.

B. The Relation of the Mica Schists to the Sandstone. We find mica schists both above the Cambrian sandstone, between it and the limestone, and also above the limestone, so that we have at least three horizons. Those below the sandstone are best seen near London Grove, Chester county; those above it, at the south foot of the North Valley Hill from Caln Meeting-house westward to the Octorara; those above the limestone at the Poorhouse quarry, Chester county, and at the quarries of the Avondale Lime and Stone Co., west of Avondale, Chester county, Pa. Those near the sandstone are sandy, not very micaceous and not garnetiferous, these above the limestone much more micaceous, frequently quite garnetiferous, in both cases conformable almost without doubt; but there is much variety, and between visible outcrops of the sandstone and limestone are large areas apparently wholly of mica schists, which are usually to be seen only as abundant fragments in the soil, but occasionally in extensive outcrops, and which cannot with certainty be placed above or below the limestone. These frequently contain garnets and occasionally staurolite and kyanite.

While in some cases these minerals may be due to contact metamorphism, as, for instance, in the vicinity of the soapstone quarry on the Schuylkill, in most of the region plutonic rocks are absent from the garnetiferous schists. In Cream Valley and westward the garnet and staurolite-bearing schists are near the Conshohocken diabase dyke, but where its contacts can be observed, as on the Schuylkill, in West Conshohocken and at the Gulf, the adjacent hydromica schist and limestone appear to be unchanged. The exposures suffice only to prove that much of the mica schist is of the age of the sandstone or more recent. In Chester county, at least, there appears to be no evidence whatever that any of the mica schists are older than the lower Cambrian. The same is true of the schists northwest of the ancient gneiss (Cream Valley and westward).

The schists of the valley between the forks of the ancient gneiss in Newtown, Edgemont, Willistown, Westtown etc., can be traced continuously into the sandstone and limestone region of Chester county without essential change. Similar schists are found on the southerly side as well as the northerly of the gneiss. On the southerly side they are very sandy, resembling those adjacent to the sandstone, but further south and especially eastward they are

highly garnetiferous, like those of Chester county associated with the limestones. The schists may be traced northeastward until at Glenside and in Huntingdon Valley, Montgomery county, we find them apparently overlying the sandstone and limestone.[192] Mr. Hall placed the sandstone and limestone in the upper Cambrian or lower Silurian and contended that these schists cannot be below the Hudson river group,[193] but the limestone being recognized as Cambrian, there seems no reason to doubt the adjacent schists being of that age.[194]

3. Are the hard gneisses of southern Delaware and Chester county of the same age as those of the Buck Ridge, or more recent ?

My reasons for thinking they are more recent are:

A. The lithological difference which has already been discussed. This would have been of little weight in districts widely separated, but here we have a hill of gneiss of similar lithological character fifty miles long and at times five miles broad, and with another belt of similar rock stratigraphically connected to the northeastward, while the gneisses and gabbros of southern Delaware county, only one to three miles distant southward, are lithologically very different and maintain this difference throughout their whole extent.

B. These gneisses can be traced eastwardly among the schists, the gneisses diminishing, the schist increasing, until they are reduced to narrow beds interbedded (or interlaminated) in the schists.

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[192] Charles E. Hall, C[6], p. 62.

[193] C[6], p. 9.

[194] Dr. Frazer, in an argument against Mr. Hall's views (*Proc. Am. Philos. Soc.*, December 15, 1882, p. 517), says: "There are small tongues and isolated patches of Laurentian rocks occurring in the midst of these southern schists. One comes into Chester county from the east in Easttown and Tredyffrin townships and another occupies a small area near West Chester. These patches are bordered on all their sides by these schists with no intervening rocks. The bordering rocks therefore cannot belong to a group above the Potsdam and the Lower Silurian limestone."

This does not agree with my observations. The ancient gneiss does come into Chester county from the east as stated, but it is about five miles wide at its entrance into Chester county, and the tongue which underlies West Chester is from one to three miles wide and extends west of the Brandywine, continuous and frequently exposed. I have been over the area carefully and have been able to find no isolated patches surrounded by schists. It is true, however, that between the ancient gneiss and the schists the sandstone and limestone do not occur, but they do occur in the schists close to the contact line.

4. What light can be thrown upon the age of the schists and gneisses embraced in Prof. Rogers' first and second groups at the Schuylkill and extending thence northeastward and southwestward ?

The advance of geological science has taught that schistosity, formerly thought to be evidence of stratification, may be due simply to dynamic and metamorphic agencies, and that one frequent result of such alteration, when not carried to an extreme, is the formation, from a more massive rock, of augengneiss or gneiss containing eyes or lenses of quartz, feldspar or other mineral having a more or less drawn-out appearance. This is very common in this region.

The remarks of Mr. Charles R. Keyes[195] in regard to the Maryland Piedmont plateau are most pertinent: " From all appearances the gneiss area was originally largely granitic, but through the agency of the enormous orographic pressure has been squeezed into its present gneissic condition."

If we concede that this granite was penetrated by dykes or sheets of basic rocks, the abundant hornblende schists may be readily accounted for. In the ancient gneiss some of the dykes are now hornblende schist, though retaining their clear dyke form with sharp contacts. The exposures in or near Concord seem to indicate that such intrusions exist.

But we certainly have in the region clastics, besides the Cambrian sandstone proper. It and the schists accompanying it and conformable with it, together with the limestone and the schists overlying it, are certainly of sedimentary origin. But in Brooks' quarry, Radnor, the rocks between the sandstone and the limestone are distinctly gneissic and apparently porphyritic, though many layers are schistose. Here pebbles of the ancient gneiss clearly attest the action of water. These are among the rocks which can be traced westward and southward around the ancient gneiss, and then eastward across the Brandywine and into Delaware county.

But the sandy mica schists and garnetiferous schists, accompanied by the sandstone as far as the southwesterly border of Delaware county, can themselves be traced almost continuously further eastward, the breaks of continuity being not great, until they come

[195] *Bull. Geol. Soc. Am.*, II, 321.

again into contact with the typical sandstone and the limestone in Montgomery county.

But there are also hard gneissic rocks, both hornblendic and feldspathic, almost always more or less schistose and dipping with the adjacent schists.

Would not the conditions be satisfied by a theory that after the deposition of the sediments they were deeply buried, penetrated by intrusions of granite and basic eruptives, subjected to intense dynamic action, of which the record is left in the plications and close foldings, sheared and faulted, until almost all trace of the original rocks is lost, and a general schistose structure more or less parallel to the strike of the ancient gneiss was developed ?

A change in the direction of the compressing force would account for the remarkable change of dip observed east and west of the vicinity of Darby creek.